Sky and TELESCOPE

Kitt Peak observatory site

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Vol. XVII, No. 10
AUGUST, 1958
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Sky and TELESCOPE

Charles A. Federer, Jr., *Editor*
Joseph Ashbrook, *Technical Editor*

Vol. XVII, No. 10 AUGUST, 1958

CONTENTS

COVER: The central and southern portions of the summit area of Kitt Peak, Pima County, Arizona, site of the new National Astronomical Observatory. The view is from the southwest, toward the granite cliffs of the south ridge, along which several telescopes are to be located, as shown in the topographical survey map on page 492. Barren Coyote Mountain is in the near background, with Pan Tak Wash at its left foot, where the Kitt Peak access road leaves Arizona Highway 86. Aerial photograph by Don Keller of Phoenix. (See page 493.)

SKY AND TELESCOPE is published monthly by Sky Publishing Corporation, Harvard College Observatory, 60 Garden St., Cambridge 38, Mass. Second-class mail privileges authorized at Boston, Mass.

Subscription: $5.00 per year in the United States and possessions; $9.00 for two years; $13.00 for three years. Add $1.00 per year for Canada, Mexico, and all countries of the Pan American Postal Union, making the total subscription $6.00 for one year; $11.00 for two years; $16.00 for three years. Add $2.00 per year for all other foreign countries, making the total subscription $7.00 for one year; $13.00 for two years; $19.00 for three years. Canadian and foreign remittances should be made in United States currency. Single copy 50 cents. Back numbers, as available, 50 cents each.

All notices of change of address must be sent one month in advance and accompanied by old and new addresses. When sending your renewal order, or writing in regard to your subscription, your current mailing address must be given. Please return our bill form with your renewal payment. Circulation staff: Nancy R. Bolton, manager; Caroline Nason; Helen B. Sniegiecki; Stacia Strong.

Editorial and advertising offices: Harvard College Observatory, Cambridge 38, Mass. Advertising manager, Henry M. Corrado. Advertising rates are listed in Standard Rate and Data Service, or sent upon request.

Unsolicited articles and pictures are welcome, bearing adequate return postage, but we cannot guarantee prompt editorial attention, nor are we responsible for the return of unsolicited material. Editorial assistants: Virginia K. Cox; Elizabeth C. Merrylees; William E. Shawcross. The principal articles are indexed in The Readers' Guide to Periodical Literature.

QUESTIONS... FROM THE S+T MAILBAG

Q. Where is the constellation of Argo, the Ship?

A. This name was formerly given to a large area south and east of Canis Major. It is now divided into four smaller constellations: Puppis (stern), Pyxis (mariner's compass), Vela (sails), and Carina (keel).

Q. What is the difference between positive and negative eyepieces?

A. A positive eyepiece has its focal plane in front of the field lens; in a negative eyepiece the focal plane lies between the eye lens and the field lens. A convenient test is to try the eyepiece as a magnifying glass; a positive one can be so used, but a negative one cannot.

Q. What is meant by the radio magnitude of a celestial object?

A. Apparent radio magnitude is a measure of the amount of radio energy received from a source, just as visual magnitude is a measure of the visible radiation. There is no internationally adopted standard; one system proposed for galaxies is defined to make the radio magnitude about equal to the photographic magnitude for normal spirals of type Sb.

Q. What is the brightest spot on the moon?

A. This is generally regarded to be the central peak inside the crater Aristarchus.

Q. Has anyone ever reported the discovery of a satellite of the planet Venus?

A. Several leading astronomers of the 17th and 18th centuries thought that they had observed satellites of Venus, but none of these "discoveries" proved to be real.

Q. Which were the last three novae conspicuously visible to the unaided eye?

A. In 1946 Nova T Corona Borealis brightened to magnitude 3, in 1942 Nova Puppis reached magnitude 0, and Nova Lacertae attained 2nd magnitude in 1936.

Q. What is the color index of a star?

A. It is a number describing the star's color, and is defined as photographic magnitude minus visual magnitude. Stars of color index -0.3 are blue; 0.0, white; $+0.5$, yellow; $+1.0$, orange; and $+1.5$, red. A few very red stars have color indices as great as $+5$.

Q. By how much has our atmosphere dimmed the light of a star seen overhead?

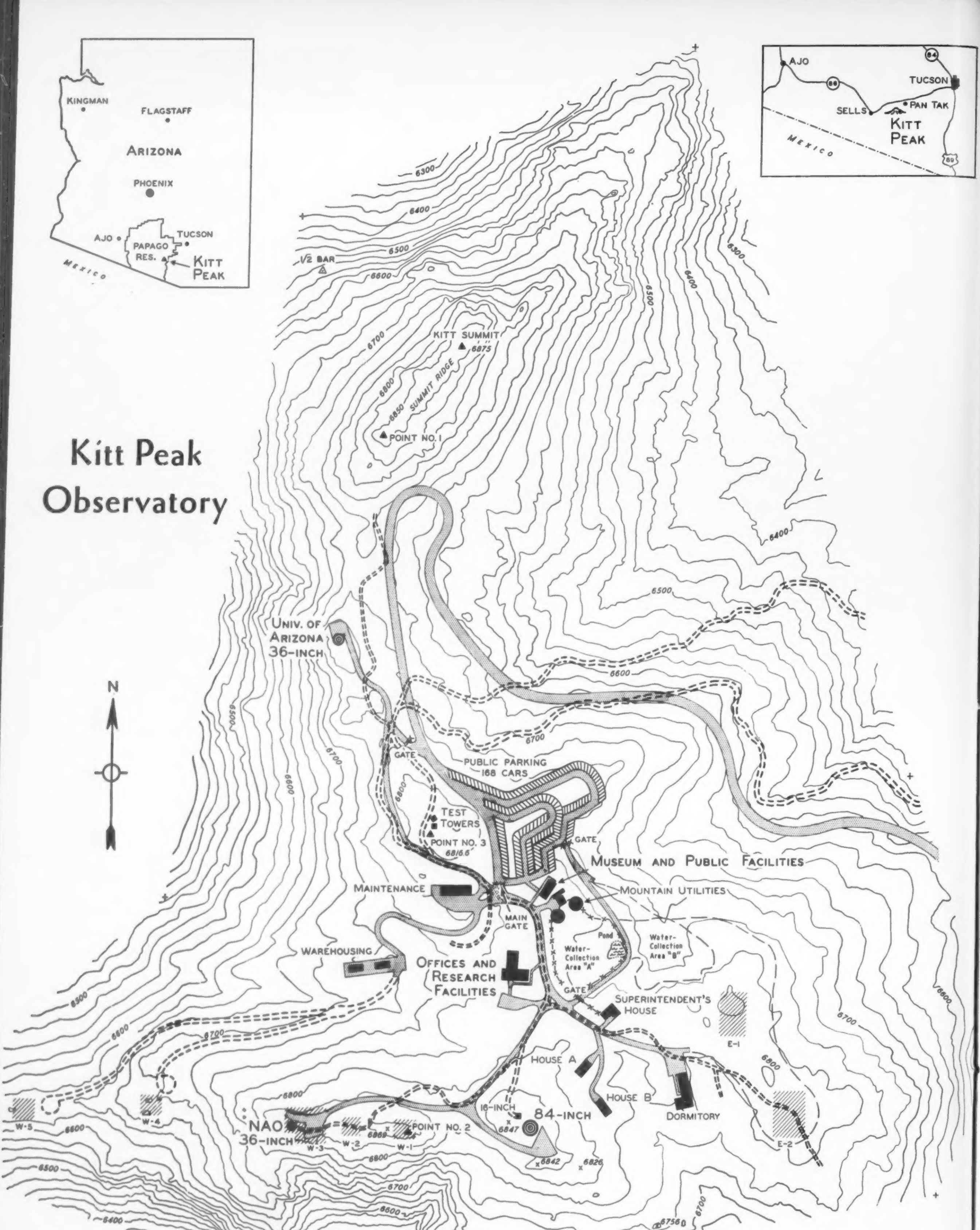
A. The light loss (atmospheric extinction) amounts to about 0.25 magnitude at the zenith; it is 0.5 magnitude at an altitude of 30°, increasing rapidly toward the horizon. These figures are for visual light.

Q. Should a person who normally wears glasses use them at the telescope?

A. Yes, many experienced observers have advised.

W. E. S.

Kitt Peak Observatory



Arizona Route 86, the Tucson-Ajo highway, 40 miles west from Tucson runs past a point about six miles north of Kitt Peak itself. There a road leads to the mountain through typical desert vegetation, past the hill from which this picture was taken. The Papago Indian village of Pan Tak lies at the distant right, on the valley floor at the foot of the mountain.

The National Observatory at Kitt Peak

ADEN B. MEINEL, *Director, National Astronomical Observatory*

CONSTRUCTION is about to begin for a new observatory that will rank among the world's foremost, on Kitt Peak in southern Arizona. The selection of this 6,875-foot mountain site, 40 miles southwest of Tucson, was announced by the National Science Foundation in March of this year. The decision was reached in Pasadena, California, on March 1-2, by the scientific committee of the Association of Universities for Research in Astronomy, Inc. (AURA), under the chairmanship of C. D. Shane.

At present, two major telescopes are planned for the new National Astronomical Observatory. Both are to be reflectors, the principal one with a mirror 84 inches in diameter, the second with a 36-inch mirror. While not the world's largest, these instruments will incorporate all of the advanced techniques of recent years. With this equipment, astronomers at Kitt Peak should be able to make effective observations of stars nearly as faint as magnitude 23.

The observatory will have other instruments. Plans are in an advanced stage for a solar tower telescope larger than any existing. We hope eventually for a reflector surpassing even one that the Academy of Sciences of the Soviet Union is designing, six meters (236 inches) in aperture. But at the present time we have the imposing task of converting an undeveloped mountain into a modern astronomical center.

Kitt Peak was selected from a preliminary list of 150 sites in six southwestern states by a three-year process of elimination. The mountain was originally noted in photographs taken from the Viking-12 rocket. Early in 1954, Helmut Abt made an aerial reconnaissance of the region, and called attention to its suitability. Later H. J. Thompson and the writer explored it on a pack-horse trip. However, access to Kitt Peak was very difficult, and the Papago Indians, in whose reserva-

FACING PAGE: At the top are small-scale maps showing the location of Kitt Peak in the state of Arizona. The large topographical map shows most of the land leased from the Papagos, with the proposed locations of instruments and permanent buildings. Present roads and trails are marked by dashed lines, while the new roads to be built are shaded. The useful area is about 70 acres, roughly in the shape of an inverted "T," extending about half a mile north and south and the same distance east and west along the south ridge, where the 36-inch and 84-inch telescopes are to be located. Five regions along this ridge, marked W-1 to W-5, are sites for present and future instruments; areas E-1 and E-2 are similar sites. The south ridge may be seen in the front-cover picture, above the bare granite face of the mountain's south side. The locations of the test towers and the Steward 36-inch reflector are given, and near the top of the chart is the summit ridge, extending from northeast to southwest. The topographic survey is based on three control points, No. 1 on the summit ridge, No. 2 on the south ridge (within W-1), No. 3, near the test towers, as identified by Fairchild Aerial Surveys, Inc.

The eastern slopes of the mountain, seen here, are the most accessible, so both the original tractor trail, built by Pima County in 1956 from Alambre Valley to the summit, and the 1957 AURA truck road ascend on this side. The tractor trail, with a maximum grade of 78 per cent, runs diagonally upward to the left from lower center. The truck road, maximum grade about 18 per cent, comes in at the right and crosses the tractor trail three times as it rises slowly to the left edge of the picture, where it turns to the right and is lost to view in the trees. The summit ridge is conspicuous in the upper right, at the northern end of the inverted "T," while the south ridge is well to the left of the 60-foot testing tower. The most distant mountains at the left are in Mexico, and the Gulf of California lies beyond them. Aerial photograph by Don Keller.

This equipment, consisting of a 6-inch folded refractor and motion-picture camera to photograph the sun's limb, has been operated daily for the purpose of evaluating daytime solar observing on Kitt Peak. The location is on the south ridge near that of the proposed 84-inch reflector, and in the background at the right is aerial-survey point No. 2, practically as high as the summit ridge. John C. Golson is operating the solar equipment, while the author watches.

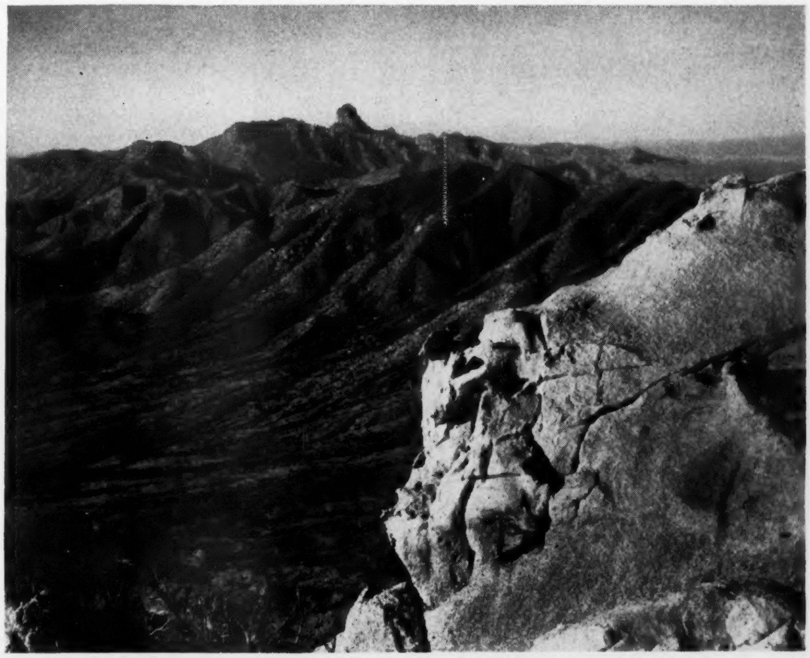
tion it is located, were reluctant to allow use of their sacred mountain for site-testing observations.

But these problems were overcome, thanks to the efforts of E. F. Carpenter, director of Steward Observatory, Alden Jones, R. A. Harvill, president of the University of Arizona, and the Pima County board of supervisors. The Papago tribe gave permission for a test site on the mountain, and the county provided the funds for construction of a tractor trail.

During the next 18 months, 30 tons of equipment were hauled up this primitive trail. Since the wear and tear on vehicles and personnel were considerable, and the excellent results of the seeing tests presaged much future travel up the mountain, a new access road was needed. A truck trail, with no grades greater than 18 per cent, was completed in the summer of 1957, and a Quonset hut was erected. This hut is topped by a water tank that may be seen in the front-cover picture of this issue ($3\frac{1}{4}$ inches from the right edge).

The test program at Kitt Peak, carried

The mountain mass drops steeply on its western side. At the left in this view is the summit ridge, to its right the rocky side of the knoll for Steward Observatory's reflector, then the testing towers. The right-hand part of the picture contains the broad south ridge, where the chief instruments will be located; compare this view with the front cover. In the background is the Alambre Valley, between Kitt Peak and Coyote Mountain, which rises toward the upper left. The neighboring mountains have a chaparral foliage cover, while Kitt Peak is amply forested with live oaks and Mexican pinon pines. Aerial photograph by Don Keller.



The Quinlan Mountains are at the northern end of the Baboquivari range, which is seen here from the south rim of Kitt Peak, not long after sunrise in May. An oddly shaped knob on the horizon is Baboquivari Peak itself, 7,864 feet above sea level and sacred to the Papagos as an abode of their "elder brother," Ee-toy. The ruggedness of this terrain is suggestive of lunar scenery. The valley in the lower left is some 4,000 feet below the camera. Kitt Peak has good air drainage on all sides, and its great height above the surrounding country prevents formation of local reservoirs of cold air. The nighttime temperature range is satisfactorily small, and of the sites tested Kitt Peak has the lowest average wind velocity.

All illustrations with this article are used by permission of AURA, Inc., and were taken by A. B. Meinel, Don Keller, or C. A. Federer, Jr.

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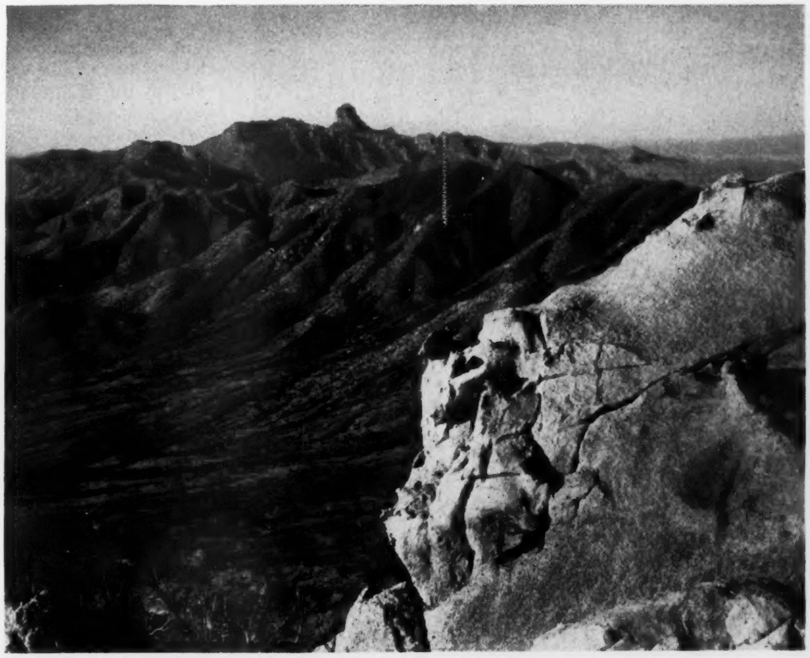

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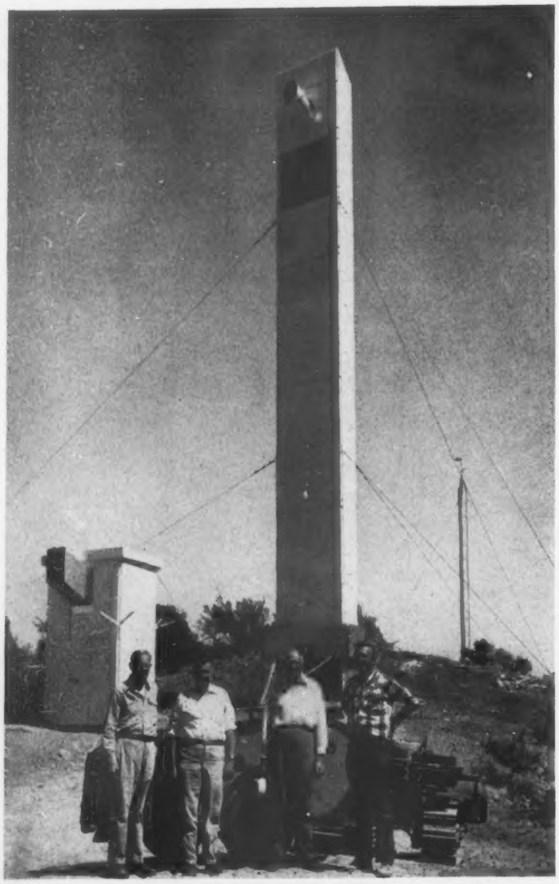
out mainly by Claude Knuckles, was started with small telescopes that automatically made photoelectric recordings of Polaris. At first, the Polaris telescope was mounted at the top of a 60-foot tower, seen in the cover picture and in several other photographs with this article. The structure consists of three concentric but independent shells, the two outer ones protecting the instrument tower from windshake. Although it was hoped that the top of the tower would not sway more than one-fourth of a second of arc, this could not be achieved economically. Therefore, instead of the tall test tower, one 10 feet high was used (see facing page).

Experience with the sophisticated automatic equipment under primitive conditions soon indicated that the station should be manned. Therefore, in March, 1957, Mr. Knuckles began visual and photoelectric observations with a 6-inch telescope.

The final choice among Kitt Peak, Hualapai (near Kingman), and Slate Mountain (near Flagstaff), was made with 16-inch reflecting telescopes at these three

On this site will rise the building for a 36-inch reflector, first telescope to be permanently mounted on Kitt Peak. The location is on the south ridge at an altitude of about 6,835 feet, near the western end of a bulldozed trail marked by dotted lines on the topographical map on page 492. The instrument will be

Above: Operations at Kitt Peak at present center around the living quarters in a Quonset hut that is well equipped, having even a television set. In the lower right of this scene is the gasoline generator for electric power. Dawn sunlight is shining on the 60-foot testing tower, while at the extreme right the summit of Kitt Peak itself is seen, about 700 yards from the hut.



Left: At the tested sites, the 60-foot towers were used to record wind velocity and temperature. The 10-foot tower, at the left, contains a telescope to monitor the pole star for astronomical seeing; it secured good records on 150 nights of the year. The remaining nights had high winds, the tracking was inaccurate, the equipment was not operating, or it was cloudy. Kitt Peak is generally favored with good seeing, but it has been somewhat poorer since the summer of 1957. Seen in this picture are, left to right, Dr. Edwin F. Carpenter, director, Steward Observatory; Dr. Frank K. Edmondson, director, Goethe Link Observatory; Dr. John C. Duncan, of Steward Observatory and former director, Whitin Observatory; and Dr. Meinel.

The author is seen on the edge of the pool of water at the lowest point of water-collection area "A." The photographer stood where a low dam will impound the water while it is being pumped into storage tanks through a filtering system.

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The final choice among Kitt Peak, Hualapai (near Kingman), and Slate Mountain (near Flagstaff), was made with 16-inch reflecting telescopes at these three places. One of these instruments was lent by William Rhodes of Phoenix. The other two were constructed by the Phoenix Engineering Company especially for the purpose, from a design by the writer. They proved so convenient to operate that a similar pattern was adopted for the 36-inch reflector now being built.

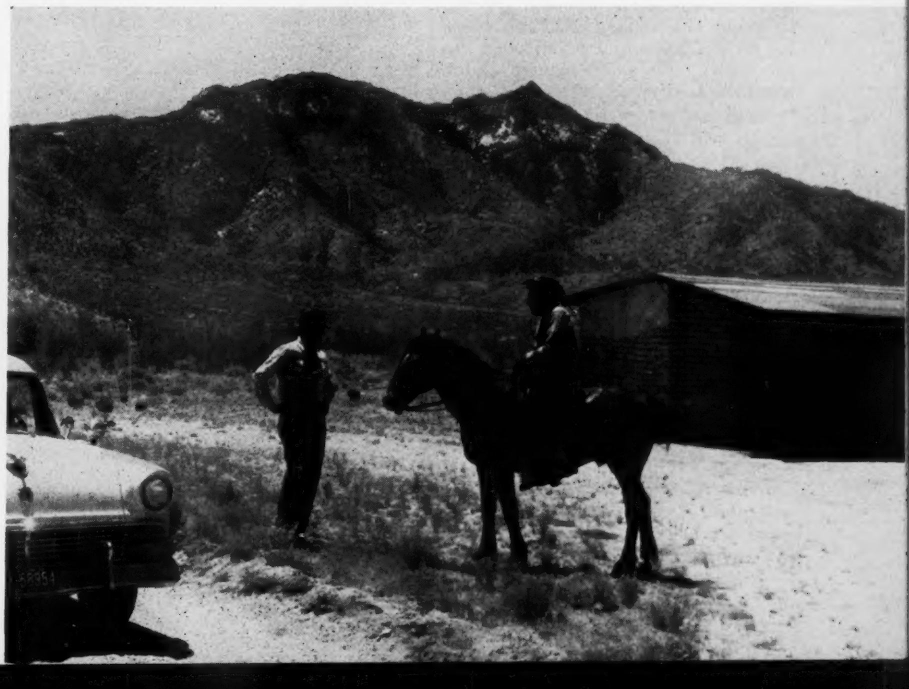
With these three instruments, standardized seeing tests were carried out at the three places, using a scale describing the visual appearance of a double star of two seconds of arc separation. After the site survey was completed, the observatory's two 16-inch reflectors went into use at Kitt Peak on a photoelectric research program.

The location of the first 16-inch instrument has been marked on the topographical map on page 492, on the south ridge not far from the proposed location of the 84-inch reflector. The 16-inch is housed in a trailer and shelter that may be seen $1\frac{1}{4}$ inches from the right edge of the front-cover picture. The primary mirror has a focal ratio of 3.5, and the Cassegrainian combination is f/13.5.

The mounting design, used for this and the 36-inch reflector, features a torque-tube polar axle, with the declination counterweight offset to the lower end of

On this site will rise the building for a 36-inch reflector, first telescope to be permanently mounted on Kitt Peak. The location is on the south ridge at an altitude of about 6,835 feet, near the western end of a bulldozed trail marked by dotted lines on the topographical map on page 492. The instrument will be built by Boller and Chivens, South Pasadena, California.

A view toward the southwest along the rocky ridge of Kitt Peak summit itself, the camera being at the highest point. It is not expected that major observing instruments will be located here. In the middle distance at the left is the knoll where the Steward Observatory 36-inch reflector will be erected.



Papago Indians are coming in contact with astronomy as they watch an observatory being built on their sacred mountain by the "men with the long eyes." A resident of the village of Pan Tak here talks with the author, who is director of the National Astronomical Observatory. The United States government is leasing the Kitt Peak summit area from the Papago tribal council, which has its headquarters at Sells. Permission has been given to build a highway across the reservation to reach the observatory.

that tube. The declination circle is large and prominent, but there is no hour circle, for the polar axle is connected directly by cable with the right-ascension and hour-angle dials in the lower right of the picture on this page.

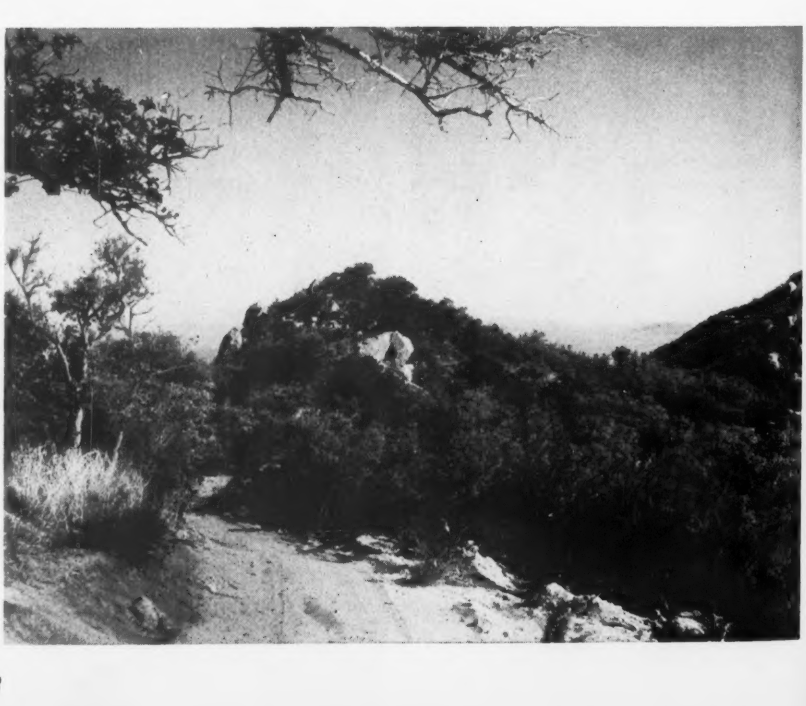
At the extreme lower end of the main telescope is seen the photomultiplier cell, as well as filter and diaphragm slides. The thin-tubed eyepiece in the lowest box section is used for guiding, and in the next box section above it is a field-viewing eyepiece. Mounted on the mirror-cell flange is a wide-angle elbow finder telescope, and a similar one is located on the free end of the declination axle.

In the final report of the site survey, the relative merits of Kitt Peak and Hualapai Mountain were listed. In rainfall, sky transparency, and darkness of the night sky, the two mountain areas are about equal. A water-supply problem exists on both. There are somewhat more clear nights on Hualapai, and the problems of road access, bringing in utilities, and land procurement would have been less than for Kitt Peak.

But the latter was rated superior on 11 counts: good seeing, low wind velocity, temperature stability, microthermal stability, upper-air trajectories, absence of airplane vapor trails, developable area on the mountaintop, southerly latitude (32° north), less interference from city lights on the horizon, the nearness of general support facilities, and proximity to an academic institution.

Water is scarce on Kitt Peak, where the rainfall is about 12 to 15 inches per year, and where few if any springs are within practical pumping distance of the summit area. Ten people living on the mountain may require half a million gallons of water per year. One solution to the water

Above: Observer Golson at the controls of one of the 16-inch telescopes being used with photoelectric photometers on Kitt Peak. After being hauled up the mountain upon a trailer, the instrument was lowered onto its mounting by a 1,000-pound bomb hoist. In this view, only part of the counterweight arm is seen, extending slightly upward and out of sight to the right.



Steward Observatory of the University of Arizona has in recent years been searching for a new location for its 36-inch reflector, as it has been hampered by the growth of the Tucson region, which now has some 100,000 inhabitants. Arrangements have been made to move the Steward instrument to the site on Kitt Peak seen here (looking north) and marked on the map on page 492. The height of this knoll is 6,800 feet. The Steward 36-inch telescope is equipped to do spectroscopic and photoelectric work, for which the observing conditions on Kitt Peak should prove very favorable.

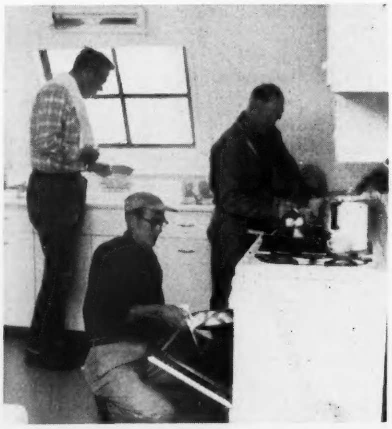
Left: Descending the present road, one finds many striking views. A route approximately 12 miles long is necessary for a modern public access road, at an estimated cost of $150,000 per mile.

Right: Where the road reaches the flat country, a stop is made to open a cattle gate, at a place marked by huge outcroppings of fractured granite. Do you see the profile of a Papago Indian who is facing westward to tribal headquarters at Sells?

problem has been proposed by W. W. Baustian (who designed Lick Observatory's 120-inch telescope). His plan is to collect rainfall by covering a three-acre natural drainage basin with a two-inch layer of sprayed concrete and wire mesh (see page 492).

Our immediate task on the mountain is the development of roads and utilities. Actual construction is scheduled to begin early this fall. Other buildings will be erected adjacent to the University of Arizona campus in Tucson, to house optical and instrument shops and to provide a base station for the resident staff and visiting astronomers. Convenient as the city is to the mountain, however, its lights are not detrimental, for mountains cut off most of them, as indicated by the front-cover photograph. Prominent on the distant horizon, about 65 miles away, is lofty Lemmon Mountain, in the Santa Catalina range northeast of Tucson. The city lies mostly between it and the lower Tucson Mountains, seen dark in front of the Catalinas. The expected urban growth of Tucson is mainly toward the east, away from the observatory.

The Kitt Peak site is being leased from the Papagos, and Congress has been asked for funds for a paved two-lane highway of five-per-cent grade up the mountain. This new road will join the highway from Tucson to make Kitt Peak easily accessible to the general public as well as to astronomers.



Despite the relative isolation of the mountain, the staff lives comfortably in the Quonset hut. Preparing breakfast are the author at the left, Mr. Golson holding the hot biscuits, and Floyd Roberson, a rancher recently turned general caretaker, who is starting the bacon and eggs on the stove.

ECLIPSE EXPEDITIONS

The only expedition from Great Britain to the October 12th total solar eclipse in the Pacific will be a group of three astronomers, H. von Klüber and Mrs. von Klüber, from Cambridge University, and A. H. Jarrett, St. Andrews University. They will go to Atafu Island in the Union group, to share a site with a team from Carter Observatory, New Zealand.

Dr. von Klüber writes: "My instruments, $1\frac{1}{2}$ tons, have been shipped already. We expect to be in Samoa the last week of August, and plan to take a Sunderland flying boat directly to Atafu, landing in the lagoon. We will establish a camp on the island itself."

The British astronomers will observe the solar corona, using an interferometer arrangement to measure the profiles of spectrum lines. Such a program was carried out at the 1954 eclipse in Sweden, but failed in Ceylon in 1955 because of bad weather. The New Zealand party plans polarimetric and photometric observations of the corona, using a special camera designed by Dr. von Klüber and used at Khartoum in 1952.

Dr. M. Waldmeier, director of Zurich Observatory, will be in charge of a Swiss eclipse expedition to Chile. He is to arrive at Santiago about September 27th, and will set up small instruments at several stations to reduce the risk of being clouded out.

WORK SUSPENDED ON 98-INCH ISAAC NEWTON TELESCOPE

Lack of funds has brought a halt to construction of the large reflecting telescope being built at the Royal Greenwich Observatory, Herstmonceux Castle, England. About $80,000 had already been spent for buildings. During a discussion in Parliament of the decision to stop work, an Admiralty spokesman stated that the project is only suspended, with hope that it can eventually be started again. The 98-inch mirror blank, which was acquired from the University of Michigan, has been ground and figured.

The Isaac Newton telescope would be the largest by a considerable margin of any in the British Commonwealth, which now has three 74-inch reflectors: at Pretoria, South Africa, at Mount Stromlo, Australia, and at Toronto, Canada; Vancouver Island, Canada, has a 73-inch.

The Robert T. Longway Planetarium is located on the campus of Flint Junior College, and has the first public installation of a Spitz Model B projector in the United States. Adjacent to the building is a reflecting pool (extreme right). The Great Lakes Region of the Astronomical League will hold its annual meeting here August 2-3. All photographs with this article are courtesy Crooks Studio.

The Longway Planetarium in Flint, Michigan

MAURICE G. MOORE, *Flint Junior College*

ANOTHER major planetarium joined an impressively growing list on June 26th, when the city of Flint, Michigan, formally dedicated its Robert T. Longway Planetarium. More than a thousand guests attended the ceremonies in which Flint Junior College was given this newest addition to its campus.

The building was opened officially when Mr. Longway, chairman of the committee sponsoring the project, pressed a button to turn on the lights illuminating the outer dome and its adjacent reflecting pool. The plan of a planetarium for this community of 190,000 population was begun four years ago by a group of businessmen interested in the cultural growth of the college and the city. From the beginning, the committee believed that either an observatory or a planetarium was needed. Because of the severity of Michigan winters, it was decided that a planetarium would better serve the public.

Ground was broken for the building on April 9, 1957. The general contractor for the project was the Erickson and Lindstrom Construction Co., and the architects were the Detroit firm of Smith, Hinchman, and Grylls. During the early months of construction, curious motorists would stop their automobiles to watch as the workmen sprayed layers of concrete over the self-supporting steel structure. Six layers of concrete in all were applied, each being cured before the next was laid on. During the winter months the entire dome structure was wrapped in a heavy transparent plastic cover, to allow the curing process to be continued.

Six layers of concrete were needed to obtain the required strength and permanence of the self-supporting outer dome of the Flint planetarium building. Part of the steel frame may be seen in this picture that was taken during construction.

Designed to harmonize with other campus buildings, the completed structure's exterior has a decorative aluminum grill, as seen in the accompanying photograph. Adjoining is a reflecting pool with a dozen spray jets.

Inside the building, the planetarium chamber has seats for 292 spectators. Surrounding this auditorium is a promenade where a visitor may see two 55-foot murals of astronomical subjects, painted on black canvas. Under ultraviolet light these pictures glow, giving a striking impression of a view into space. On the facing wall are display cases containing models illustrating many astronomical principles.

From the promenade the visitor enters

the planetarium chamber. The great projection dome is constructed of thin strips of perforated aluminum, attached to a triangularly reinforced superstructure.

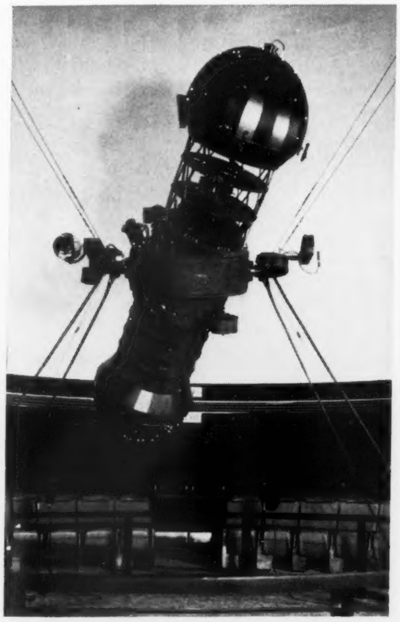
The planetarium projector is a Spitz Model B, the first to go into operation in North America. It was designed and built by Spitz Laboratories, Yorklyn, Delaware. The 11½-foot-long instrument is similar to that in Montevideo, Uruguay (*Sky and Telescope,* July, 1954, page 292, and May, 1955, page 282), and to the one soon to be dedicated at the Air Force Academy, Colorado Springs, Colorado.

The projector is supported in the middle of the chamber by four 3/16-inch steel aircraft cables, from the ceiling to the instrument's east-west axis. Four other cables to the floor hold the 1,100-pound projector rock-steady in this unusual design. As the lights dim, the cables seem to vanish, leaving the device apparently floating in mid-air.

Surrounding the planetarium chamber, which is 60 feet in diameter, is a promenade with two 55-foot murals of astronomical objects, which glow under ultraviolet illumination. The Great Nebula in Orion, two inches from the left, is over five feet high; M31 and the Ring nebula are easy to identify.

Among the 3,083 stars shown, the 54 of magnitude 2.0 and brighter are projected by individual lens systems; the rest are produced by tiny holes in the 36-inch star globes. The hole is only 0.0135 inch in diameter for a 5.8-magnitude star, the faintest shown. Realistic sharpness of the star images is achieved by using the concentrated brilliance of a zirconium-arc lamp.

The projector can simulate the astronomical phenomena of an entire day in as little as one minute, and it can run through a year in 12 seconds. Demonstrations can be given of solar and lunar eclipses, different forms of the aurora borealis, comets, and meteor showers. Of particular value in teaching astronomy and navigation are special projectors for sky co-ordinates.



The Spitz Model B has special optical projectors for the brightest stars and the moving planets. Most of the stars are produced by pinhole projection from the globes at the ends of the dumbbell-shaped instrument.

In the design of the Flint planetarium, an effective and versatile sound system is a most important part. Spaced around the dome are 16 speaker systems; with these the lecturer can produce stereophonic sound or, by turning a switch, can cause the source of the sound to move circularly around the chamber. These arrangements allow music to enhance the illusion.

The planetarium began its schedule of public showings on June 29th with "Summer Skies over Michigan." For the rest of the summer, demonstrations will be given at 8 p.m. on Tuesday through Saturday, and at 2 p.m. on Tuesday, Saturday, and Sunday. Beginning in September, there will be at least six performances daily, four of them for students. Admission is 65 cents for adults, 25 cents for those 18 and younger.

A six-week course called "Family Astronomy" is being presented by the Mott Foundation and the Flint Astronomy Club. It is a survey of basic astronomy for beginners, treating constellations, celestial motions, the sun, artificial satellites, and meteors.

A great planetarium like that at Flint may be regarded as an investment in the scientific future of our country. Perhaps, through the use of this marvelous astronomical device, one boy or girl can be inspired to develop the curiosity of a Newton or the imagination of an Einstein.

LETTERS

Sir:

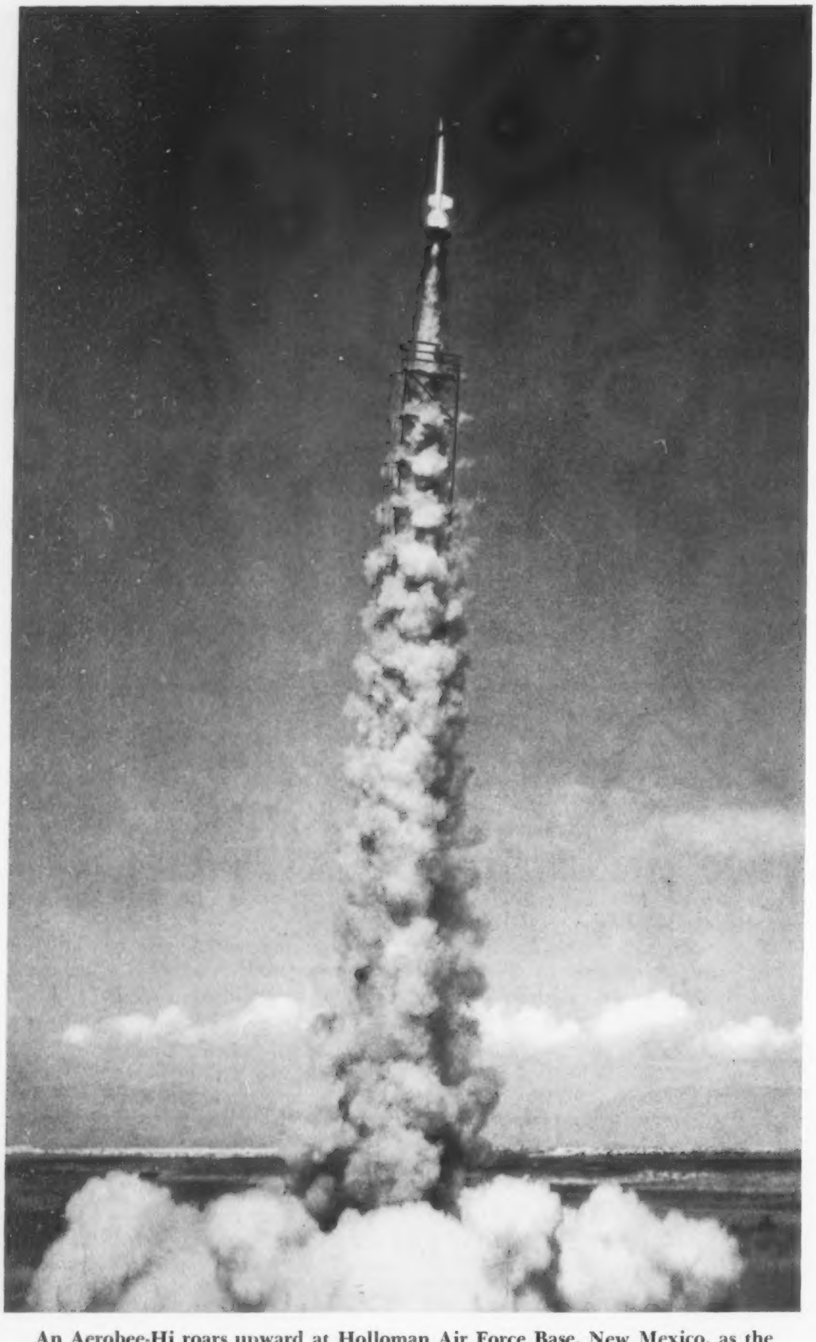
Henry C. King's article in the July issue (page 440) is mistaken in saying that the London Planetarium is the first in the British Commonwealth. There are planetariums at McMaster University, Hamilton, Ontario; at the Science Museum, Halifax, Nova Scotia; and there is one in New Zealand. All three of these were in operation before the London installation. The Canadian planetariums are referred to on page 207 of the June, 1957, issue of the *Journal* of the Royal Astronomical Society of Canada, and on page 121 of the June, 1958, issue.

ROBERT B. JOHNSTON
112 Old Forest Hill Rd.
Toronto 10, Canada

Sir:

On page 441 of the July issue, the top picture is printed upside down. In that view of part of the London planetarium projector, the positions of the mechanical eyelids are clearly wrong — the planetarium stars would shine on the floor and in the audience's eyes while the dome would be blank!

GEORGE LOVI
14 Eleventh St.
Lakewood, N. J.



An Aerobee-Hi roars upward at Holloman Air Force Base, New Mexico, as the launching tower is wreathed in smoke from the rocket's exhaust. The tower is tilted slightly to prevent a misfire from falling back on the launching site. U. S. Air Force photograph.

Rocket Ultraviolet Solar Spectroscopy

WILLIAM A. RENSE

University of Colorado

ABOVE the earth's blanket of air there is a vast range of radiations from the sun, moon, planets, stars, nebulae, and other celestial objects that do not penetrate the atmosphere to observers on the ground. These radiations often hold the key to improved understanding and new discoveries about the astronomical universe.

Rockets that carry instruments high enough to reach these radiations before they are absorbed serve as small observatories above the atmosphere that sample the intrastellar radiation. In a sense, the rocket programs represent man's first step to move his observatories spaceward.

Observations of the ultraviolet solar spectrum from rockets are an effort to unlock some of the mysteries concerning the sun's radiation at wave lengths shorter than about 2850 angstroms. An appreciable payload has to be lifted at least above the ozone layer of our atmosphere, and preferably much higher. The instruments must in some way be pointed at the sun and equipped with radio transmitters to telemeter the data they record, or must have parachute mechanisms so the records can be examined directly when the rocket has returned to earth.

Rocket research in this field got under way in 1946 when a successful flight was organized by a Naval Research Laboratory group. Since that time many other successful attempts have been made by NRL, as well as by the Air Force Cambridge Research Center (AFCRC) and the University of Colorado.

The solar atmosphere. The sun's radiations pass through or originate in its extensive atmosphere, shown schematically in the sketch. Many of our modern theories about the solar atmosphere are only tentative, and will undoubtedly be modified considerably as more data are obtained.

The sun's *photosphere* is the nearest thing to a true surface that we can speak of. It represents the first optically opaque region encountered in going downward into the sun from the outside; it may be of the order of 100 miles thick. The temperature of the photosphere is 6,000° absolute, and the density about 10^{16} particles per cubic centimeter. What lies beneath the photosphere is known only through scientific inference.

From the interior of the sun radiation streams out through the photosphere into a rarefied layer only a few hundred miles thick, labeled R in the diagram. This layer consists mostly of hydrogen and helium, with a little of practically all the other chemical elements in gaseous form. The temperature is known to be relatively low, about 4,700° in places. There is considerable absorption of light from the hotter photosphere by the mostly neutral atoms here, with the result that many of the characteristic dark lines of

the visible region of the solar spectrum originate in this layer. For this reason, it is sometimes called the *reversing layer.*

For a cause not yet understood, the next layer, *H,* is hotter than the layer below it, being about 7,000° absolute. It is perhaps 2,000 miles thick. If we assume that energy is in some way supplied to the gases in this layer to maintain the temperature, many of the hydrogen atoms should be ionized, along with atoms of some heavier elements. The ultraviolet spectral lines of these ions would appear in either absorption or emission, depending upon solar conditions.

The layer marked *He,* about 12,000 miles thick, has a still higher temperature, 20,000°, fixed approximately by the ionization of helium atoms. Here the atoms are stripped of even more of their electrons than in the *H* layer.

The outermost part of the sun's atmosphere, labeled *C,* is known to have an extremely high temperature, of the order of a million degrees absolute, although it is very rarefied, with a density of at most 10^9 particles per cubic centimeter. The combination of high temperature and low density leads to considerable ionization. As many as a dozen or more electrons have been knocked off some atoms, and these highly ionized atoms emit their characteristic wave lengths in the ultraviolet and visible regions of the spectrum.

Layers *R, H,* and *He* are often referred to together as the *chromosphere,* while the envelope marked *C* is the *corona* of the sun. They are described here as distinct homogeneous layers, but this is an oversimplification. Prominences and sunspots are shown in the diagram, but other important solar features, such as spicules and flares, are omitted.

The radiations we observe by rocket spectroscopy have originated in the photosphere or in one or more of the solar atmospheric layers. They pass through the solar atmosphere, perhaps being partly absorbed or scattered; thence they travel across space and penetrate the earth's atmosphere, where they may again be partly absorbed or scattered. From our rocket spectrograms, we seek to infer the true history of this radiation.

The earth's atmosphere. Relatively little of the sun's powerful short-wave radiation penetrates to the lowest layers of the terrestrial atmosphere. These are the troposphere, *T,* and the stratosphere, *S,* together about 20 miles thick, and within which the gases are well mixed. A low temperature of 190° absolute occurs in the stratosphere, and at the top* of that layer the pressure is only 0.01 atmosphere.

Though not very thick, the *Oz* layer is important because the chemical composition of the air there changes significantly with increase in height. A new substance, triatomic oxygen or *ozone,* is relatively abundant, probably being formed by solar ultraviolet light acting on the oxygen in the atmosphere. The temperature of the ozone layer is higher than that of the stratosphere.

Above the ozone layer, it is more difficult to classify the various parts of the atmosphere. There are radical changes in chemical composition, very low pressures, considerable ionization, and, amazingly enough, temperatures as high as 1,000°. This *upper atmosphere* contains atomic oxygen, sodium atoms, atomic and molecular nitrogen, electrons, and heavy atoms.

*Some authors define the stratosphere as extending upward above the D layer of the ionosphere.—ED.

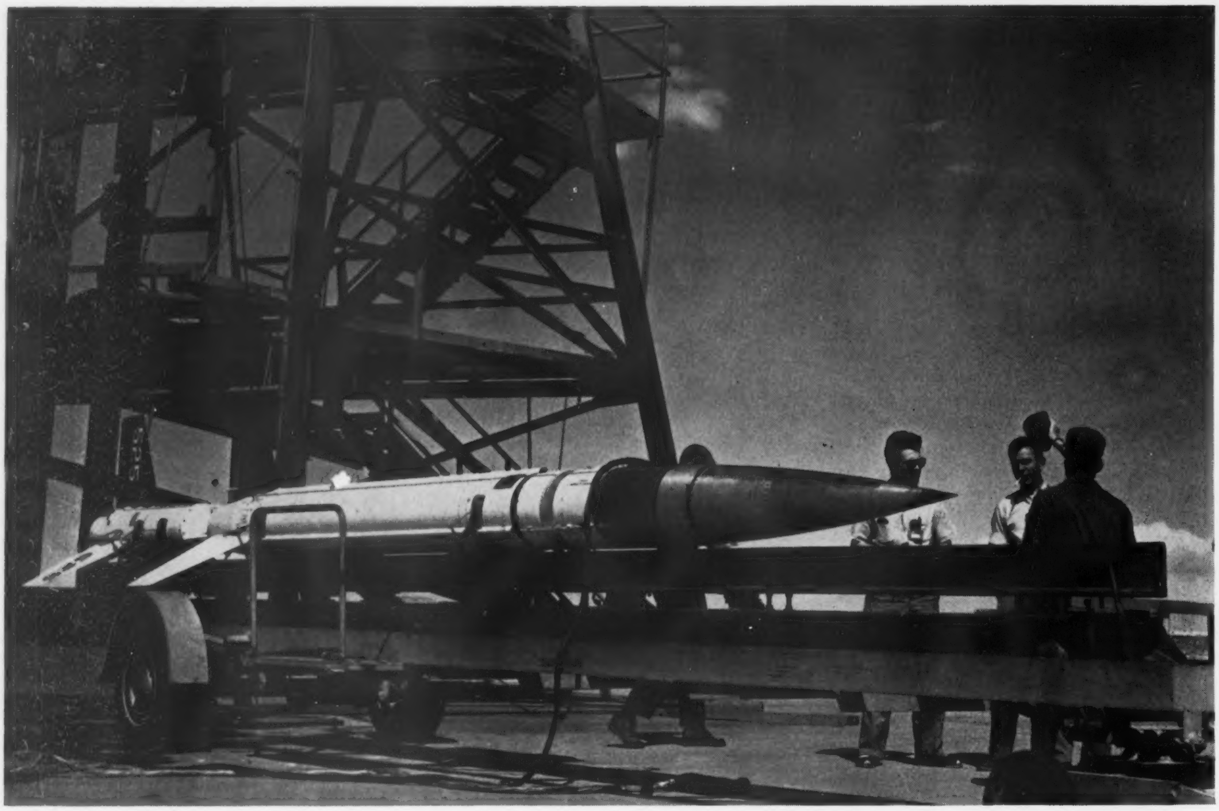
For convenience in describing the ionization, some scientists speak of the *ionosphere,* divided into three layers: D about 40 miles up, E at about 75 miles, and F about 150 miles high (the F layer splits into two during the daytime). The point of maximum ionization is in the F layer about 170 miles up. These layers are not distinct divisions, but regions of slightly enhanced ionization in an atmosphere that has ions everywhere.

Thus, in addition to carrying instruments above the highly absorbing lower layers of the atmosphere, rockets may help to answer such questions as: What causes the ionization of the air? What causes the changes in chemical composition with height?

The rockets. The Aerobee rocket has played the major role in solar ultraviolet spectroscopy. At first, however, the V-2 and the Viking were employed, and later the Deacon, Cajun, Asp, and Loki. Early Aerobees were small, and reached about 70 miles, but two later types, Intermediate Aerobee and Aerobee-Hi, carry typical payloads to heights of around 130 miles, where their instruments can detect considerably more of the solar ultraviolet radiation.

One of the launching towers for Aerobee rockets is located at Holloman Air Force Base, Alamogordo, New Mexico, and is tipped a few degrees from the vertical for purposes of range safety. Some of the rockets have a solid-fuel booster to assist starting. After takeoff, this is dropped, then the rocket's liquid fuel burns out, and the missile coasts upward to the top of its trajectory. At about 40 miles, where air resistance is nearly negligible, the doors on the nose cone are

The structures of the atmospheres of the sun (left) and earth are compared in these two University of Colorado diagrams, which are not to scale. Radiation coming from the sun's photosphere and observed at the earth's surface is scattered and absorbed by every layer it traverses. The aim of the spectroscopist is to infer the properties of each of the layers from its effects on the solar radiation.



Aerobee 47 has had the instrument-containing nose section attached, and has been fueled. Here it is resting on its dolly, ready for raising into the tower. The rocket and the I-beam to which it is secured will be tilted upward as a unit. The rear set of fins is attached to the booster, which will drop off shortly after firing. These pictures are courtesy U. S. Air Force.

ejected automatically and the detecting instrument exposed.

In most experiments an electronic "sun-seeker" automatically points the instrument directly at the sun. During much of this part of the flight, the rocket spins rapidly around its longitudinal axis, about once each second, and wobbles like a top (precession) in a period of about two minutes. These are the important motions the sun-seeker must neutralize.

The rocket spectrograph was badly damaged by impact during the nonparachute landing of Aerobee 47. The film can ordinarily be recovered safely in such cases, thanks to its shockproof container.

The rocket moves very slowly when near maximum height, but gains speed rapidly during descent. At this time, if film has been exposed, it is rolled up into a lighttight, shockproof cassette, and the whole instrument is automatically tucked into the nose cone. At a suitable time the nose cone is separated from the rest of the rocket by an explosion, both parts then being slowed by the denser lower air because they are aerodynamically unstable. Automatic release of a parachute provides for safe landing of the nose cone, with its instrument and sun-seeker, on the desert floor. To locate this jettisoned equipment amid the wide expanse of wasteland sometimes means a lengthy search.

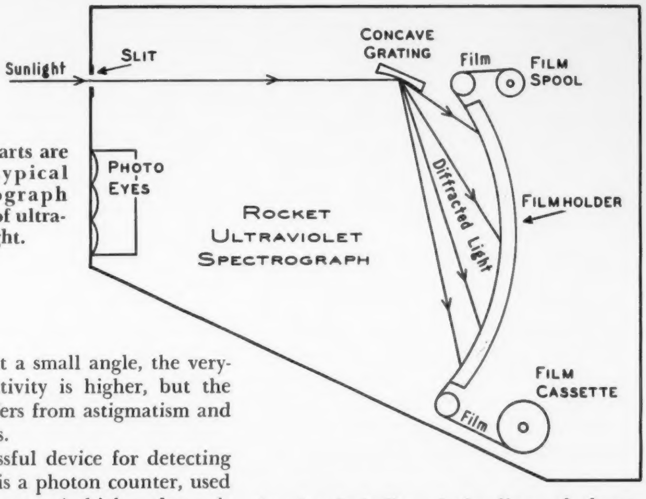
During the entire flight, telemetering equipment is active, reporting on the rocket's flight behavior and the performance of the sun-seeker and detector. When no film is used, the observer must rely solely on the telemetering for his data. If parachute recovery is not successful, the ground search for records is often tedious, but although the spectrographs may be smashed the film may be safely recovered. Sometimes even optical parts such as gratings are intact.

The spectrograph. For photographing solar ultraviolet radiation from a rocket, a concave-grating spectrograph is commonly used. Sunlight passes through a slit onto the grating, where it is dispersed and focused on the film. The slit, grating, and film are all on a circle (called the Rowland circle), which has a diameter equal to the radius of curvature of the concave grating.

The film is automatically advanced after each exposure, or filmstrips may be placed on a drum that rotates between exposures, bringing each strip in succession along the Rowland circle. Special Eastman film is used, either SWR or 103-O UV-Sensitive, suitable for the far ultraviolet range from 3000 to 100 angstroms.

The casing for the optical parts has baffles to let air escape as the rocket rises. Also attached to the spectrograph chamber are the "fine eyes" of the sun-seeker.

In normal-incidence spectrographs, the light from the slit strikes the grating nearly perpendicularly, but the reflectivity of the grating drops off rapidly below 500 angstroms. In the grazing-incidence type, where light meets the grating surface at a small angle, the very-short-wave reflectivity is higher, but the arrangement suffers from astigmatism and other aberrations.



The principal parts are shown for a typical rocket spectrograph used in analysis of ultraviolet sunlight.

Another successful device for detecting solar ultraviolet is a photon counter, used by the NRL group. A high voltage is applied to gas in a chamber, but current flows only when a high-energy photon penetrates the gas and ionizes it momentarily. By choosing a gas with a suitably high ionization potential, the observer can be sure that no photons having less than a certain energy will be counted. Thus, he may limit his record to solar radiation shorter than 1350 angstroms by using nitric oxide (see page 446 of July).

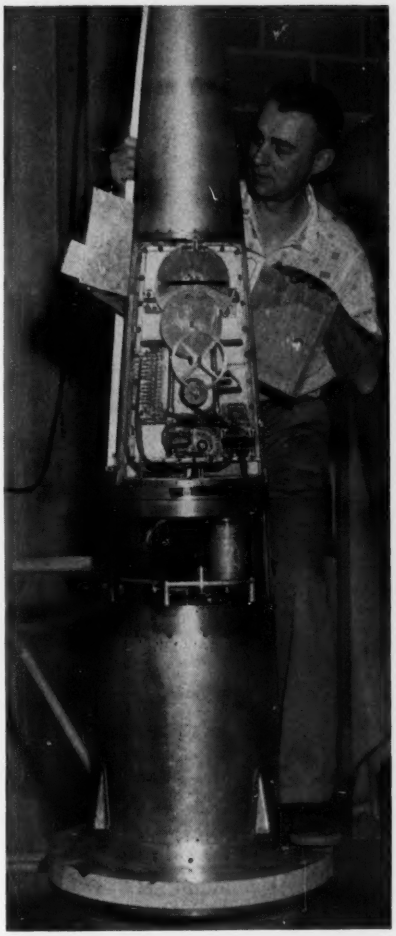
A new sensitive detector developed at AFCRC works somewhat like an ordinary photomultiplier tube, but the sensitive surface has a high work function — releasing electrons only when high-energy (far-ultraviolet) photons impinge on it.

The sun-seeker. From two to five minutes of observing time are available during a rocket flight. Not only must high-speed spectrographs be used, but they must be constantly pointed at the sun. At the University of Colorado, we have developed a sun-seeker to keep the spectrograph correctly oriented within the rocket.

Sunlight is received by the error sensors, which are photosensitive germanium transistors. Coarse sensors are used for approximate pointing, then fine ones for accurate aligning. Their signals, proportional to the error in direction, are fed through mixers, phase inverters, and power amplifiers to activate the servo motivators. Liquid magnetic clutches produce the torque, attaining pointing accuracy of about one minute of arc.

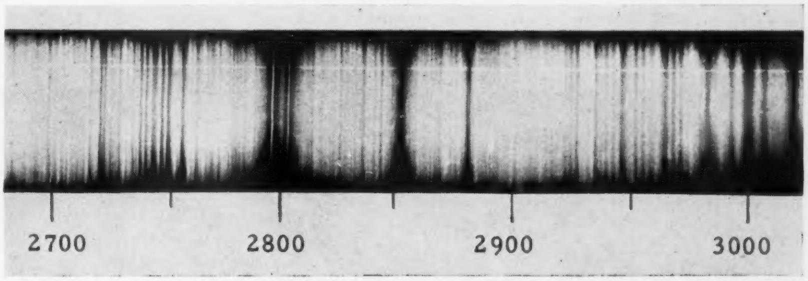
Results of rocket flights. Before the time of rocket spectroscopy, the sun's ultraviolet spectrum had been observed only down to about 2850 angstroms. The earth's lower atmosphere, especially the ozone layer, masked the spectrum beyond this point. When the first rocket pictures were taken at heights well above the ozone layer, astronomers found that down to about 2000 angstroms the spectrum was like that in the visible region — continuous radiation of the photosphere crossed by the dark Fraunhofer lines of absorption in the solar atmosphere.

An important new discovery in this region was the two emission lines in the center of the absorption lines of ionized magnesium at about 2800 angstroms, which show clearly in the accompanying spectrogram. However, the continuous radiation in the 3000-to-1800-angstrom region is less than that expected from the photosphere's temperature of 6,000°.

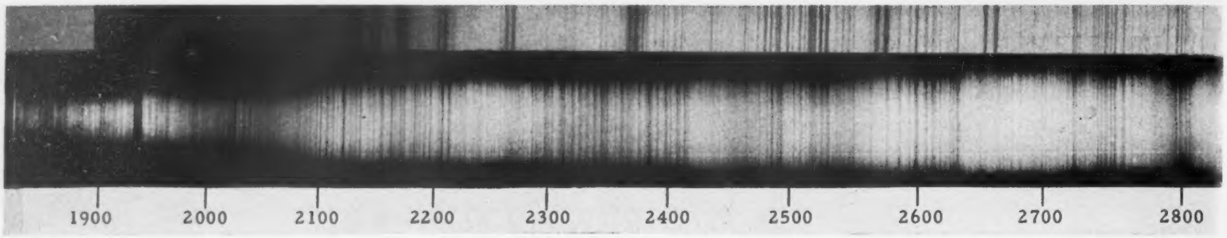


The nose cone of an Aerobee-Hi has been opened to reveal the gear section of the pointing control. Removal of another panel on the other side of the cone gives access to the electronic components. The compartment at the bottom contains the battery, motor, and clutches for the pointing mechanism. U. S. Air Force photograph.

In the solar spectrum between 2650 and



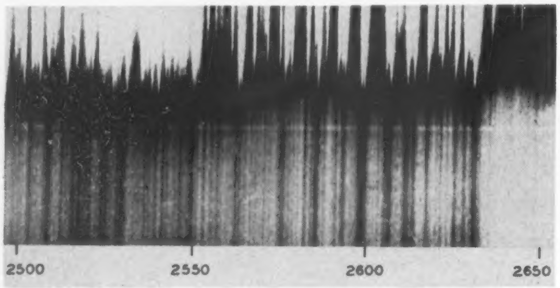
The near-ultraviolet solar spectrum between 2700 and 3000 angstroms, from an exposure of 5.2 seconds at a height of about 110 kilometers above the earth's surface. Note the two sharp, intense emission lines of ionized magnesium near 2800 angstroms, appearing white in this positive reproduction. University of Colorado photograph.



The upper spectrum (negative) is of impure aluminum, photographed in the laboratory. The lower spectrum (positive) is of the sun; evidently the weakening around 2000 angstroms is partly caused by aluminum vapor in the solar atmosphere. Calcium vapor also contributes to this effect. On this page are University of Colorado spectrograms.

2500 angstroms reproduced below, compare the dark lines with the bright ones at the top. The latter come from the light of an iron arc in the laboratory; it is clear that many of the solar absorption lines in this spectral region are due to iron. The known wave lengths of these iron lines allow measurement of the wave lengths of all the other lines. About 1,500 new lines in the solar ultraviolet are now being measured by this method.

One of the most striking features of the new spectrograms is the sudden drop in intensity in the continuum around 2000 angstroms. This effect was unexplained for some time, but it is now known to be caused mainly by the absorption by aluminum and calcium beyond their series limits. Only for these elements do the limits lie in the correct spectral region, and both metals are relatively abundant in the sun's atmosphere.



Part of a laboratory spectrum of an iron arc (above) matches lines in the solar rocket spectrum (below). Such correspondences make it possible to set up a scale of wave lengths for the ultraviolet spectrum of the sun.

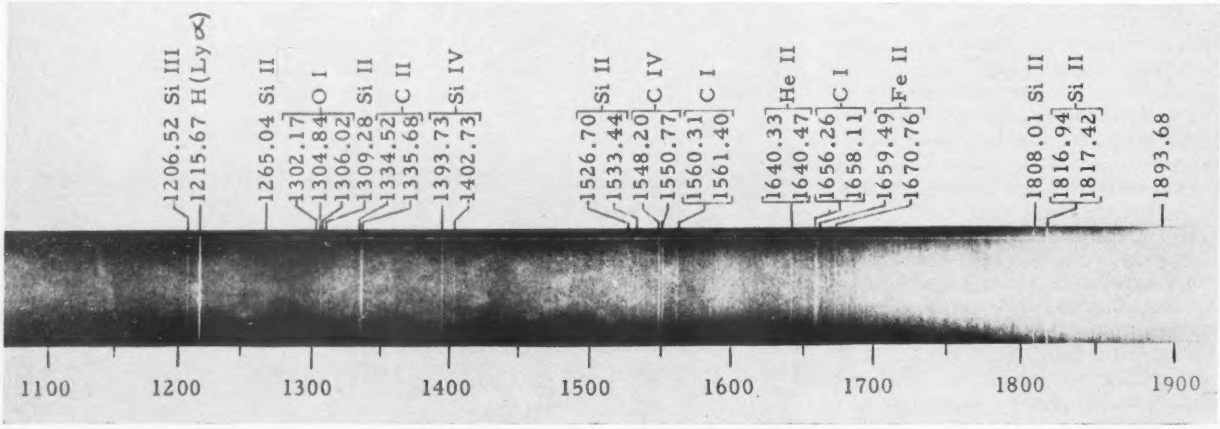
The truly exciting part of the new spectra lies below 1900 angstroms, where many emission lines occur, the most prominent being Lyman alpha of hydrogen at 1216 angstroms. The emission lines, mostly due to ions, are believed to originate in the hotter regions of the chromosphere. Although the continuum is very faint in the accompanying spectrogram, it has been observed down to about 1500 angstroms, and it contains absorption as well as emission lines.

The Lyman-alpha line. The half width of the Lyman-alpha (Ly α) line is about one angstrom, an important finding astrophysically because it indicates something of the temperatures, pressures, and depths of the hydrogen layers that emit this radiation. Photographic and photon-counter intensity measurements indicate that Lyman alpha may vary during the sunspot cycle. Values from 0.1 to six ergs per square centimeter per second have been measured. This line's intensity may also depend on the day-to-day aspect of the solar disk, varying by a factor of as much as two or three.

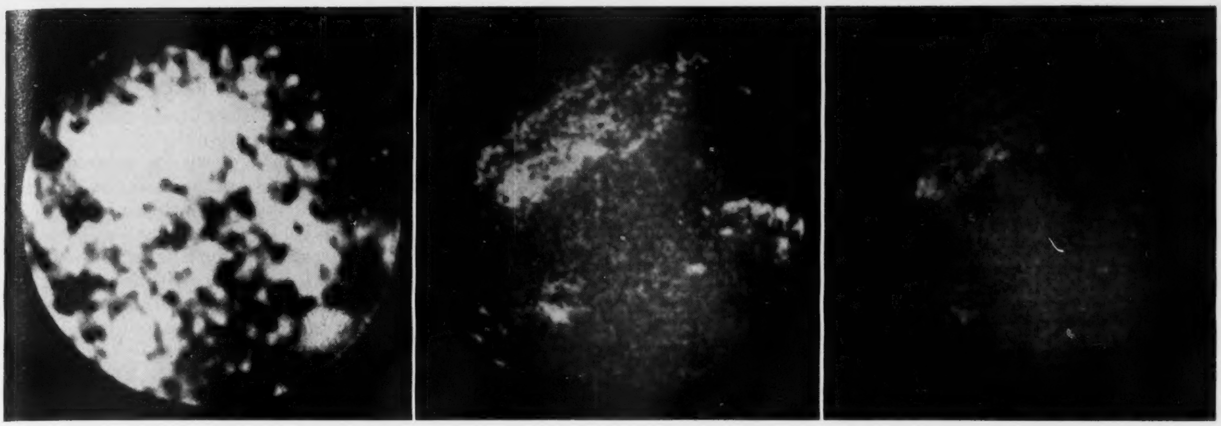
In the three solar pictures opposite, the left shows the sun in Lyman-alpha light, photographed by a specially designed rocket camera with lithium-fluoride optics. The center and right views, taken at McMath-Hulbert Observatory on the same day as the rocket picture, show the sun in ionized calcium light at 3934 angstroms (the K line) and Balmer hydrogen-alpha at 6563 angstroms, respectively. It will be seen that enhanced Lyman-alpha radiation occurs in those areas that contain hydrogen-alpha and ionized-calcium plages.

If we take as an average value three ergs per square centimeter per second for the intensity of Lyman-alpha radiation, a simple calculation shows that this is about two-millionths of the total solar energy output in the visible region. Small as this is, however, solar Lyman alpha may play an important role in some phenomena of the earth's upper atmosphere, such as the formation of ionization layers, because such short-wave energy has strong ionizing powers.

Since Lyman-alpha light is not readily absorbed by nitrogen and only slightly by oxygen, it can penetrate to as low as



The solar spectrum between 1100 and 1900 angstroms, photographed from an Aerobee-Hi rocket on August 6, 1957, at an altitude of about 150 kilometers. This 89-second exposure shows many identified emission lines, due to hydrogen, helium, carbon, oxygen, silicon, and iron. (In a June, 1958, rocket flight, the spectrum was photographed to wave lengths as short as 100 angstroms.)



Three views of the sun, in far-ultraviolet, violet, and red light, in which the same active regions of the solar surface can be recognized. At the left is a rocket-camera photograph in Lyman-alpha light at 1216 angstroms. The others are McMath-Hulbert Observatory spectroheliograms in ionized-calcium light at 3934 angstroms (center), and in hydrogen-alpha radiation at 6563 angstroms (right).

50 miles above the earth's surface. Most of its effect is probably in the D layer. According to one theory, this region results from the action of Lyman alpha on nitric oxide, believed to be present in the atmosphere at that height. Since D-layer disturbances lead to difficulties in radio communications, this problem is important.

Radiation shorter than 1000 angstroms. Spectrograms have been taken that show emission lines even a little below 1000 angstroms. There is a gap in the data from this point down to the soft X-ray region. This does not mean that no solar radiation is there, but that rockets have not yet been able to carry suitable instruments high enough to be clear of the heavy absorption effects of molecular nitrogen. Moreover, spectrographs become much less sensitive in this range, requiring longer exposures and a reduction in the background of scattered light. Photon counters cannot be used because no window materials transparent at these wave lengths are known.

Astrophysicists predict interesting possibilities for this region. For example, there may be some very intense lines originating in the solar corona. It is expected that strong lines of neutral and ionized helium will be present, and the Lyman continuum stretching below 912 angstroms may be detectable.*

It was with some surprise that rocket spectroscopists, by means of special photon counters, measured appreciable amounts of solar X-rays between one and 100 angstroms. Most of this occurs between 40 and 100 angstroms, is fairly constant, and is observed on all occasions. But the emission at shorter wave lengths is more variable in character; for example, at *very* short wave lengths it is much stronger at the time of solar flares.

A large part of the sun's X-ray emission corresponds to that of a gray body at 500,000° absolute, but the X-ray flux at very short wave lengths may at times indicate as high as 4,000,000°. These results are not completely explained, although the corona, with its high temperatures and highly ionized atoms, may be a source. Cosmic rays are known to be emitted by the sun, and X-rays are likely to be associated with them. Some of the X-rays can penetrate far into the terrestrial atmosphere – even down to the D layer – and contribute to atmospheric ionization.

These results, and those described by Otto Struve (page 445, July issue), hint at the exciting future possibilities in rocket spectroscopy, and the interesting information that the rocket solar ultraviolet program can yield.

**Added in proof:* The University of Colorado group on June 4, 1958, successfully flew in an Aerobee-Hi rocket a specially designed grazing-incidence spectrograph that has closed the gap between 1000 and 100 angstroms. In particular a strong He II line at 303.8 angstroms was photographed. This is the resonance line in the spectrum of ionized helium that corresponds to hydrogen Lyman alpha. The He I resonance line at 584 angstroms is very weak compared to He II at 303.8.

OBSERVING THE SATELLITES

Long-Range Visibility Forecasts

FOR weeks at a time, an artificial satellite may remain observable only from a particular zone of geographical latitude. There is a need for an approximate method of preparing world-wide long-range forecasts of the visibility zones for satellites. The possibility of a sighting depends on whether the relative positions of the satellite and the sun place the illuminated moonlet above the horizon of an observer whose sky is dark enough. Because the relative positions of the satellite orbit, sun, and earth change rather slowly, almost the same geometrical situation prevails during successive crossings. Thus the conditions at any one latitude alter gradually, so we may speak of a visibility zone bounded by parallels of latitude.

Visibility forecasts should be distinguished from the predictions made to aid the search for an object at some later crossing. Such search predictions, which normally are accurate to a few minutes of time and to a few degrees of arc, are issued by the Smithsonian Astrophysical Observatory from optical observations, and by the Naval Research Laboratory from radio data. These relatively accurate and detailed ephemerides are given for only a short period in advance – in the case of $1958\delta 1$ and $\delta 2$, two weeks at most. This is because the desired accuracy can be maintained only by frequent corrections to the orbital elements, which are liable to small erratic changes from variable air drag. This difficulty, which is greatest for low satellites, was described by L. G. Jacchia on page 278 of April.

But if we do not ask for the exact time of a future crossing, or for the precise position of a satellite, the problem of long-range forecasting is much simplified. Merely to extend a search ephemeris into the future would involve much wasted effort; instead, it is advantageous not to compute the position of the satellite in the orbit, but to regard the orbit itself as an observational entity. Taking geometry into account, we can then determine the range in latitude within which the orbital ellipse is suitably presented for observation on some particular future date. The writer knows of no systematic long-range forecasts on a world-wide basis having been undertaken previously.

The chart on the next page is an example of such long-range predictions of evening and morning periods of visibility. It has been prepared for $1958\delta 1$, the rocket carrier of Sputnik III. The vertical scale shows the northern and southern latitude limits of the zone of detectability,

and allows the observer to find whether the satellite will be visible from his *latitude* on a particular date; the diagrams do not indicate whether his *longitude* is appropriate for a sighting.

Even at perigee, 1958δ1 can be seen from places some 600 miles from the subsatellite point. Since in mid-latitudes successive crossings are separated by about 1,200 miles, it is therefore likely that any observer, regardless of his longitude, will be able to see the object at least every two or three days during a visibility period.

In preparing these charts, it was assumed the satellite could be seen if it crossed at least six degrees above the horizon at a time when the sun was six degrees or more below it. Refraction by the atmosphere was allowed for in computing where the satellite would emerge from the shadow of the earth; the satellite at emergence was supposed visible at the moment it received illumination from the upper edge of the sun. These are extreme conditions for naked-eye visibility, based on experience at our Cambridge research station.

The computations used orbital elements provided by the Smithsonian on June 26th, with corrections from our observations. Approximate allowance was made for the shift of the node and perigee; from this shift the uncertainties of the diagrams may grow to two or three days by mid-September. Part of the calculations were performed with a small analogue computer, constructed by H. Amory, Mr. and Mrs. W. R. Battersby, and others at the research station. The calculations utilized tables prepared by my wife.

During a typical visibility period, the conditions under which the satellite may be viewed will change progressively. This can be illustrated by experiences during the mid-June crossings of Sputnik III. Early in that interval, observers near latitude 40° north were able on favorable mornings to see either δ1 or δ2 or both, but the sightings were difficult because sunrise was close. Traveling in slightly different orbits from southwest to northeast, both objects passed into the bright sky as they neared the rising sun.

But a few days later, the orbit planes had shifted sufficiently westward so the crossings were earlier, and both moonlets were readily followed by the unaided eye over a long arc across a dark sky. During the final days of the visibility period, the continuing westward displacement of the orbit planes led to progessively earlier times for emergence from the earth's shadow, the emergence point meanwhile moving northward. Finally, only the most northern part of the satellites' paths were illuminated by the sun from far below the horizon.

These changes illustrate the general rule that the middle portion of any visibility interval will be the most favorable, since then the satellite will cross the meridian at a greater angular altitude and against a reasonably dark sky.

The First Space Traveler

THE DOG in Sputnik II "endured well" the rigors of launching and travel in orbit, according to a recent Soviet statement giving the first release of scientific information gained from observations of both Sputniks I and II. This preliminary report dealt with the Sputniks' orbits, the atmospheric density, ionospheric exploration, and cosmic rays, as well as biological studies of Laika, the dog encased in Sputnik II.

Some information about the animal's reactions was given: "The behavior and condition of the animal during Sputnik's ascent to the orbit were registered quite fully. Telemetric data transmitted from the satellite indicated that during the ascent heart contractions approximately trebled, as compared with their initial frequency, but returned to normal when the satellite went into orbit."

The dog withstood its temporary increase in weight as the rocket accelerated, and its subsequent weightlessness in orbit did not cause any essential or long-continued change in the dog's physiological functions. According to the Soviet account, of the many problems that must be solved before manned spaceflight becomes a reality, several of the most serious seem to have been lessened by the dog who lived for many days aboard Sputnik II.

Shorter Notes

EXPLORER III was probably last observed on June 28th at 2:31:24 Universal time, by the MOONWATCH team at Memphis, Tennessee, of magnitude +8 and at an altitude of 28 degrees, due south of the station. Thirty-two revolutions earlier, Wichita, Kansas, probably saw the same object, magnitude +7.

From these two observations a period of 89.6 minutes was calculated for June 27.1. According to Smithsonian astronomer Charles Whitney, the critical period of 87.75 minutes would have been reached within about a day after the Memphis sighting, and 1958γ would then have failed to rise from its perigee height, thus ending its career.

Only an extremely fortunate combination of sightings will make possible the recapture of the lost satellite 1958β1 (Vanguard I's carrier rocket). This is the conclusion reached at the Smithsonian Observatory by Robert Briggs, who pointed out that several reliable, well-distributed observations within a span of a few days will be needed to allow computation of a preliminary orbit. Because of β1's faintness (magnitude roughly 7 or 8), only a few sightings were secured soon after launching, some of them erroneous; no observations later than the end of April have been reported to June 30th.

An unusual satellite observation was made by Lyle T. Johnson of Welcome, Maryland, who saw Vanguard I visually on April 14th as an object of the 13th or 14th magnitude. He used a 10-inch reflector with a low-power eyepiece giving a 1.9-degree field. Location, direction of motion, and time agreed closely with predictions by the Naval Research Laboratory. This difficult sighting was of a 6.4-inch sphere when it was 2,385 miles from the observer!

Techniques and devices for predicting the apparent position of a satellite have been developed by many observers. It is expected that this topic will be discussed in a later issue; readers are invited to send the writer their procedures.

MARSHALL MELIN
Research Station for Satellite Observation
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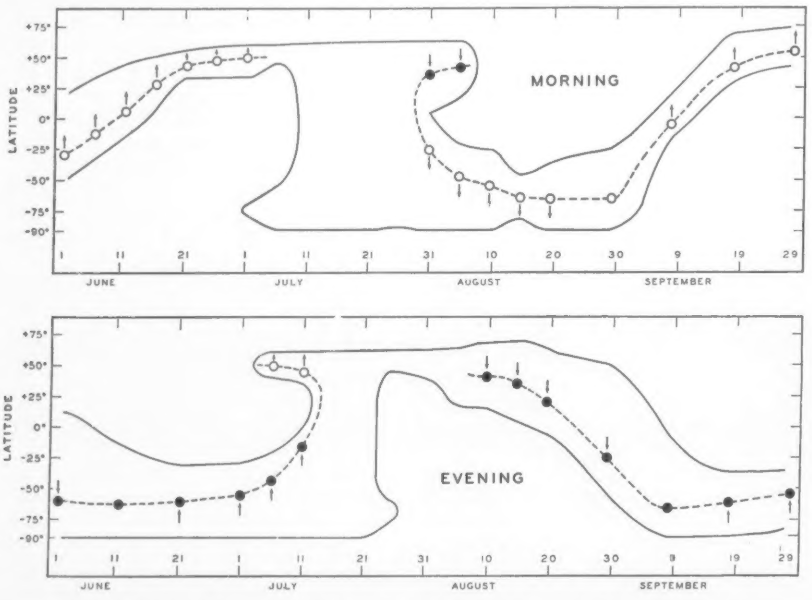


The author's visibility prediction chart for the Sputnik III rocket case.

ASTRONOMICAL SCRAPBOOK

The Great Paris Telescope

PERHAPS you were a visitor at this year's Brussels Fair and saw the display of Maksutov telescopes and other astronomical optics in the Soviet pavilion. It seems that no international exhibition is quite complete without astronomical instruments of novel design or unprecedented size. The tradition is an old one; it goes back at least as far as the 1893 Columbian Exhibition in Chicago, where wondering crowds gazed at the huge 40-inch refractor soon to be erected at Yerkes Observatory.

As fairs go, the Paris Universal Exhibition of 1900 must have been one of the most striking ever held, even without the benefit of modern high-pressure publicity. Some 51 million persons visited the immense fairgrounds that stretched along both sides of the river Seine, and on one gala evening 22,000 mayors of French municipalities sat down to dinner as the guests of President Emile Loubet.

Since France at that time was a leading nation in the manufacture of precision optics, it was fitting that one of the French buildings at the exhibition should be a Palais de l'Optique, and it was natural that this should contain the largest telescope in the world.

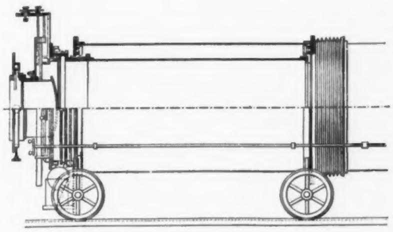
That instrument was the project of a syndicate headed by Francois Deloncle. At first, a reflector of 120 inches aperture was considered, but facilities could not be found for casting a glass mirror blank of such unprecedented size. Finally, a 49.2-inch refractor of 187 feet focal length was decided upon. A telescope of this enormous length could not be mounted in the ordinary manner inside a dome. Instead, a fixed horizontal tube was used, into which starlight was reflected by a siderostat mirror 79 inches in diameter.

The firm of Mantois cast the 50-inch blanks for two objectives, visual and photographic, and after many unsuccessful trials the Jeumont glassworks provided a satisfactory disk for the siderostat mirror. The figuring and polishing of the optical components were carried out by P. Gautier, the leading French maker of large telescopes, who also was responsible for the mounting.

To permit focusing, the eyepiece assembly was a four-wheeled carriage on rails. With the lowest power, 500x, the field of view was only three minutes of arc, but celestial objects could be easily located, thanks to the accuracy of the mounting and its adjustments. The observer was connected by telephone with an assistant at the siderostat who could read the setting circles and operate the controls. A brief conversation – "more right ascension," "easy does it," and "back up" – would suffice to get the desired object centered in the eyepiece field. The weight-driven clockwork of the siderostat functioned so well that a star would stay in view with 500x for 45 minutes without the need for using the slow motions.

The throngs of visitors who lined up for a look through this great instrument were turned away at midnight, when E. Antoniadi of Juvisy Observatory would take his place at the eyepiece for observations of nebulae.

Antoniadi's drawings of the Ring nebula in Lyra, NGC 7009 in Aquarius, and a few other planetaries seem to represent the only attempt to make any scientific use of the 49.2-inch refractor. As reproduced in the *Bulletin* of the Societe Astronomique de France for 1900, they are rather disappointing, and probably do not show much (except for faint field stars) that could not be detected visually with much smaller apertures.



For focusing, the telescope's eyepiece end could be shifted five feet on rails.

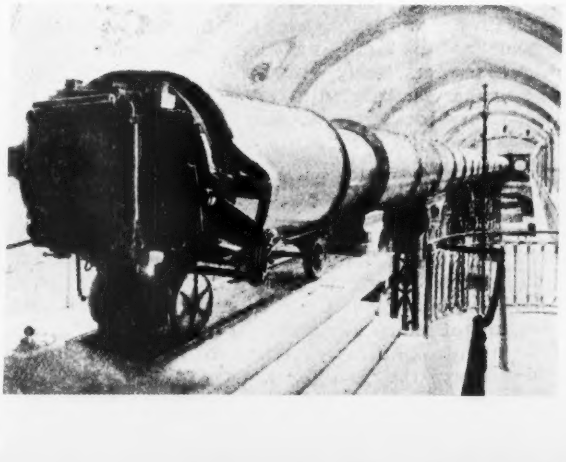
The Paris siderostat mirror was $6\frac{1}{2}$ feet in diameter and one foot thick.

The meagerness of these results was partly due to the very unfavorable location of the telescope, amidst the searchlights of the fairgrounds and the smoke of a great city. In addition, the quality of the seeing must have been seriously impaired by the use of a steel tube without any provision for adequately ventilating its interior.

When the Paris exhibition of 1900 closed, the heavy financial investment in the telescope had been only partially met by the admissions collected. Deloncle's syndicate tried unsuccessfully to sell the French government the instrument, and it was finally broken up, the optical parts being stored at the Paris Observatory.

In addition to the dubious merit of having shown that the telescope of the future would be of a different type, the Paris giant enjoyed for about a year a clear title as the largest refractor in the world. Perhaps it should also be called the largest telescope of that day, as Lord Rosse's historic 72-inch reflector had been inactive since 1878, and the Mount Wilson 60-inch reflector was not to be completed until 1908.

JOSEPH ASHBROOK



The 49.2-inch Paris refractor, seen from near the tailpiece. The latter carried a holder for photographic plates 30 inches square. The three pictures on this page are from the British journal "Nature" in 1900.

NSF RESEARCH GRANTS

Research proposals to be considered at the September 19-20 meeting of the advisory panel for astronomy of the National Science Foundation should be submitted before September 8th. While the foundation can accept suitable proposals at any time, those of an unusual nature should be presented for review by the panel. Inquiries should be addressed to the Program Director for Astronomy, National Science Foundation, Washington 25, D. C.

Eight galaxies in Pavo, photographed with Radcliffe Observatory's 74-inch reflector on September 2, 1954. Eastman 103a-O emulsion was used without a filter for this one-hour exposure; the scale reproduced here is 4.8 seconds of arc per millimeter. All of these objects are faint, most of them probably barred spirals or elliptical galaxies.

Among Southern Galaxies—VII

BOTH PICTURES this month show galaxies in the far southern constellation of Pavo. A grouping of eight faint exterior systems may be seen at the top of this page. NGC 6872, the large one at the upper right, is at right ascension $20^h\ 11^m.7$, declination $-70°\ 57'$ (1950 co-ordinates). It is a late-type barred spiral, SBc or SBd. Noteworthy is its very long, faint brush which extends from the upper (northern) arm to the left (east).

The bright elliptical system just below the center of the picture is NGC 6876, and immediately to its left is a fainter elliptical, NGC 6877. Another two inches east is NGC 6880, and near it is fainter NGC 4981, both possibly barred spirals. Just above NGC 6872 is a faint elliptical, IC 4970. Almost midway between NGC 6872 and 6876 lies a small uncatalogued galaxy, and an edgewise system, IC 4972, is about an inch from the bottom and three inches from the right edge of the field.

On the facing page is a magnificent triple system, its brightest member being NGC 6769, at $19^h\ 13^m.9$, $-60°\ 35'$. This galaxy is of photographic magnitude 11.9, and G. de Vaucouleurs has classified it in his new scheme as a peculiar object of type SAB(r)ab. It is interacting with another peculiar galaxy, NGC 6770, type SB(rs)b. The latter is strongly distorted, and is linked to NGC 6769 by an anomalous arm.

The third member of the group is NGC 6771, an SA0 spiral seen almost edgewise. Its conspicuous dark lanes are not evident in the low-resolution photograph with the Mount Stromlo 30-inch reflector reproduced on page 584 of the October, 1957, issue.

The distances and red-shift velocities of these three objects are unknown, but if they belong to the great Pavo-Indus cloud of galaxies, they are perhaps 40 or 50 million light-years distant.

FACING PICTURE: Three galaxies forming a compact system in Pavo. This is a one-hour exposure without a filter on an Eastman 103a-O plate, September 21, 1954, with Radcliffe Observatory's 74-inch reflector at Pretoria. The strong distortion of NGC 6770, at the left of NGC 6769, clearly indicates the interaction between them. The third object is NGC 6771. The scale is 1.8 seconds of arc per millimeter. North is at the top.

These two pictures are more in the series begun in February, 1958, from the Cape Photographic Atlas of Southern Galaxies, printed by permission of R. H. Stoy, director of the Royal Cape Observatory, Cape of Good Hope, South Africa.

A Problem in Celestial Motions

Otto Struve, *Leuschner Observatory, University of California*

THE STORY of Lagrange's straight-line points is a rather striking example of how an idea born nearly 200 years ago in a study of planetary perturbations can find fresh applications in the age of modern stellar astronomy and artificial satellites. Let us approach the subject by some simple cases of celestial motions.

It was at the dinner of the American Astronomical Society in Berkeley, California, in August of 1956, that I offered a valuable old book by P. Gassendi as a prize to the first person who could answer this question: A meteorite is at rest with respect to the earth, at a distance of 239,000 miles; how long would it take to fall to earth (neglecting our planet's finite size)? The dinner guests were given five minutes to find the answer.

The solution follows rather directly from Kepler's third law of planetary motion, and the society's president then, D. H. Menzel of Harvard Observatory, took only about one minute to win the prize.

There is a hint in the wording of the question, for 239,000 miles is the average distance of the moon, and the period of our satellite in its roughly circular orbit is 27.3 days. Kepler's third law states that the square of the period is proportional to the cube of the orbit's semimajor axis. Thus, for the moon we have

$$27.3^2 = c \times 239{,}000^3,$$

where c is a constant whose numerical value does not concern us in this example.

The straight-line orbit of the meteorite is an extreme case — a degenerate ellipse with the earth's center at one end of the orbit. Therefore, the semimajor axis of the meteorite's orbit is just half that of the moon's, and for the meteorite

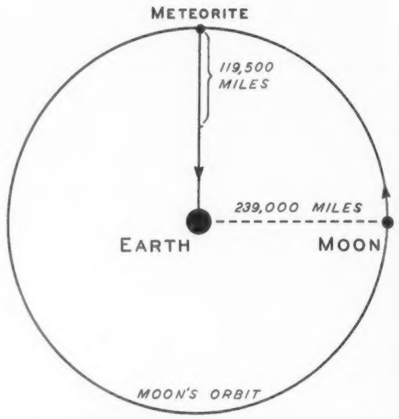
$$P^2 = c \times 119{,}500^3.$$

Dividing the second formula by the first gives

$$P^2/27.3^2 = \tfrac{1}{2}^3,$$

and the period, P, of the meteorite is nearly 10 days. The duration of the fall is, of course, one half of this, or about five days.

This result tells us that if we were to fire a rocket vertically into space, with just enough initial speed for it to reach the moon's orbit before turning back (neglecting any attraction by the moon),



The straight-line orbit followed by a meteorite falling to the earth from the moon's distance is illustrated here.

it would take about five days to go that far. A distance of 100,000 miles from the center of the earth would require a flight time of 1.3 days, while 478,000 miles (twice the moon's distance) would need about 13.7 days.

In more accurate calculations, in which the radius of the earth is allowed for, these times would be slightly smaller.

Let us now consider the problem of launching an artificial satellite in the plane of the earth's orbit in such a way that it would remain apparently stationary against the background of stars for a long time, seemingly anchored in the sky. It would have to be raised to the proper height and given the proper eastward velocity to travel around the earth once in 24 hours.

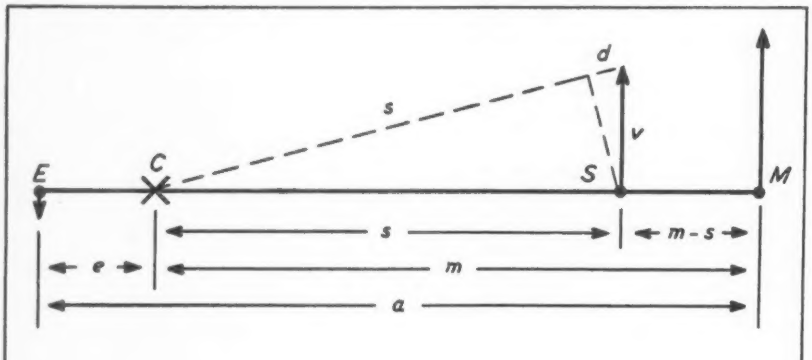
Again we can make use of the moon's motion and Kepler's third law:

$$1^2/27.3^2 = D^3/239{,}000^3,$$

where D is the distance of the artificial satellite from the center of the earth; it turns out to be 26,400 miles. The vertical flight time to attain this height would be about eight hours, and the satellite would then have to be given a horizontal velocity of roughly 7,000 miles per hour to stay in a circular orbit.

A related problem is that of placing a satellite on the straight line joining the centers of the earth and the moon. Is there some location along this line such that the satellite would always remain in front of the moon, eclipsing the central portion of the lunar disk? (We shall assume the moon's motion to be uniform.)

An elementary solution to this problem was recently given by M. Minnaert of



$$e = \frac{aM}{E+M}$$

$$m = \frac{aE}{E+M}$$

$$v^2 + s^2 = (s+d)^2$$

$$v^2 + s^2 = s^2 + 2sd + d^2$$

Neglect d^2 as it is very small:

$$d = v^2/s$$

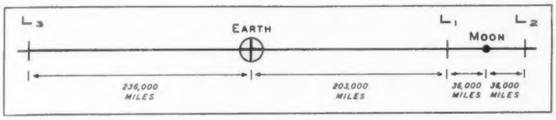
$$\text{Acceleration} = 2d = v^2/s$$

This diagram depicts the problem of finding the location of an artificial satellite that is to remain constantly on the line between the earth and the moon. Arrows show the motion in one second of the satellite and of the earth, E, and the moon, M. The derivation of the acceleration of the satellite toward the center of gravity, C, of the earth-moon system is shown by the formulae.

Utrecht, Holland, in the Dutch popular astronomical magazine *Hemel en Dampkring*. We shall use the following symbols and the diagram on the facing page, which is self-explanatory:

a, earth-moon distance, 239,000 miles
E, earth's mass, 6×10^{27} grams
M, moon's mass, 7×10^{25} grams
S, satellite's mass
G, gravitational constant, 6.7×10^{-8} (centimeter-gram-second units)
v, satellite's orbital velocity.

The center of gravity of the earth-moon system is located at a distance e from the earth and m from the moon, the sum of these distances being equal to a. Because the mass ratio E/M of the earth and moon is 80, e is $0.012a$ and m is $0.988a$. (The center of gravity actually lies inside the body of the earth.) We shall make the assumption that the orbits of the earth, moon, and satellite around the center of gravity are all circular.



The location of the Lagrangian points L_1, L_2, and L_3 in the earth-moon system.

In order that the satellite at S be in equilibrium between E and M, the sum of the forces acting on S must be zero. There are three such forces:

1. The earth's gravitational attraction on S, which is $GES/(e+s)^2$.

2. The moon's gravitational attraction on S, or $-GMS/(m-s)^2$. The minus sign indicates a force directed away from the earth.

3. The centrifugal force, f, due to the orbital motion of S around C, which can be calculated in several steps:

First, evaluate the distance d by which S falls toward C in one second, as shown in the diagram. The corresponding acceleration is twice the distance of fall, or v^2/s. The force equals mass times acceleration (Newton's second law of motion):

$$f = -Sv^2/s.$$

Second, impose the condition that the satellite always remain on the straight line EM, making its period, P, equal to that of the moon. Kepler's third law, with the constant factor given explicitly, becomes

$$P = 2\pi a^{1\frac{1}{2}} [G(E+M)]^{-\frac{1}{2}}.$$

Third, eliminate the velocity v from the expression for centrifugal force, using the fact that the circumference of the satellite's orbit is $2\pi s$, and $v = 2\pi s/P$. Substituting the value for P given above, we have

$$v = s[G(E+M)]^{\frac{1}{2}}/a^{1\frac{1}{2}}.$$

Consequently, the centrifugal force acting on S is found by substituting this value for v in the $-Sv^2/s$ formula, so

$$f = -GsS(E+M)/a^3.$$

Now we can set the sum of the three forces, 1, 2, and 3, equal to zero, thus stating the satellite's equilibrium condition:

$$GES/(e+s)^2 - GMS/(m-s)^2 - GsS(E+M)/a^3 = 0,$$

in which the factors G and S may be canceled, to give

$$E/(e+s)^2 - M/(m-s)^2 - s(E+M)/a^3 = 0.$$

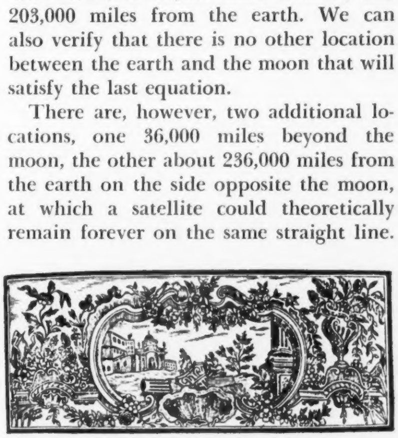
This equation may be further simplified if we express all distances in units of the earth-moon distance, so that $a = 1$, $e = M/(E+M)$, and $m = E/(E+M)$. Dividing the equation by $E+M$ and substituting gives

$$m/(e+s)^2 - e/(m-s)^2 - s = 0.$$

Since m and e are already known to be 0.988 and 0.012, respectively, the equation can easily be solved, for example by trial and error, to give $s = 0.838$. This is the distance, in terms of a, of the satellite from the center of gravity. Its distance from the earth is $e + s$, or 0.850, and from the moon it is $m - s$, or 0.150.

In this way we have found that a satellite which is to remain in front of the moon must be 36,000 miles from it, and 203,000 miles from the earth. We can also verify that there is no other location between the earth and the moon that will satisfy the last equation.

There are, however, two additional locations, one 36,000 miles beyond the moon, the other about 236,000 miles from the earth on the side opposite the moon, at which a satellite could theoretically remain forever on the same straight line.



ESSAI
SUR
LE PROBLEME DES TROIS CORPS.

Juvat integros accedere Fontes.
LUCR.

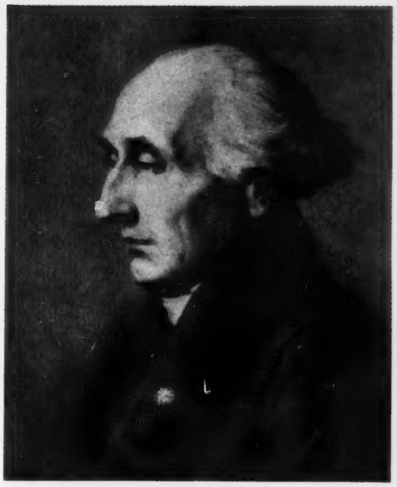
CHAPITRE PREMIER.

Formules générales pour la solution du Problême des trois Corps.

I.

SOIENT A, B, C les maffes des trois corps qui s'attirent mutuellement en raifon directe les maffes, & en raifon inverfe du quarré les diftances ; foient nommées de plus x, y, z les coordonnées rectangles de l'orbite du corps B

Lagrange's "Essay on the Problem of Three Bodies," in which he announced the discovery of his equilibrium points. This memoir won the prize of the Paris Academy of Sciences in 1772.



The Lagrangian points are named after Louis Lagrange (1736-1813), the greatest French mathematician of his time. He made important contributions to celestial mechanics.

These three positions, L_1, L_2, and L_3, have been known to astronomers since 1772, and are referred to as Lagrange's straight-line solutions of the restricted three-body problem. They play an important role in many astronomical questions.

For example, in the earth-sun system the L_2 point is about one million miles from the earth in the antisolar direction. The Swedish astronomer H. Gylden suggested many years ago that the gegenschein – the very faint diffuse glow in the sky directly opposite the sun – consists of a cloud of meteoric particles that tend to linger in the vicinity of L_2 during their orbital motion around the sun.

In the sun-Jupiter system, the L_2 point lies on the line joining the sun and Jupiter, about 30 million miles beyond that planet. Thus if there is a swarm of meteoric bodies forming a Jovian gegenschein, it would lie about a third of an astronomical unit from Jupiter.

The locations of the points L_1 and L_2 are also important in defining the region around a planet in which a satellite can be permanently retained. The moon, 239,000 miles from us, is well inside the critical distance of one million miles. But the outermost satellites of Jupiter are about 15 million miles from their primary. Thus they are now within the critical distance of 30 million miles and are fairly stable, but relatively small perturbations by other bodies or a decrease in the mass of Jupiter could allow them to escape.

Another important application of the Lagrangian points is in the study of gaseous streams in close binary-star systems, a topic I discussed in *Sky and Telescope* for December, 1957.

We have seen that a satellite placed *exactly* at one of the points L_1, L_2, or L_3, and provided with *exactly* the right orbital velocity, can remain forever in the

same position relative to the earth and moon. But what will happen if it is placed close to yet not at one of the Lagrangian points, or is provided with a slightly incorrect velocity? If the satellite would tend to remain in the vicinity of the particular Lagrangian point, we would call its motion *stable;* if it moved away indefinitely from the Lagrangian point, the motion would be *unstable.*

The English astronomer H. C. Plummer proved in 1901 that all three solutions are in general unstable: "If the infinitesimal body were displaced a very little from the points of solution it would in general depart to a comparatively great distance." (F. R. Moulton, *An Introduction to Celestial Mechanics,* second edition, page 302, 1914). However, G. Darwin and Moulton were able to show that if the departures from the correct position and motion of the satellite obey certain conditions, the small body will make a number of loops around the Lagrangian point before pursuing its path into other regions.

In practice it would be extremely difficult, if not impossible, to place an artificial satellite precisely at the Lagrangian point and provide it with just the correct circular velocity. All we could hope for is to approximate these conditions, and have the satellite execute a few oscillations around the Lagrangian point before wandering off. According to Moulton, the period of each oscillation is about six months, being longest at L_2 and shortest at L_1.

An interesting instance of these phenomena was studied by Mrs. Nancy L. Gould of Leuschner Observatory. For the eclipsing binary system of Algol, she has calculated the trajectories of particles ejected radially from different places on the equator of the less massive star, all with the same initial velocity. Some of the ejected particles fall back toward the parent star, and others tend to form a ringlike structure around the more massive body. There are a few particles that describe loops around the Lagrangian point L_3.

From these examples, we can glimpse something of the wide range of applications of Lagrange's idea of equilibrium points, even in branches of astronomy undreamed of during his lifetime.

PLANETARIUM SYMPOSIUM AT CRANBROOK

A symposium on planetariums and their educational uses will be held at the Cranbrook Institute of Science, Bloomfield Hills, Michigan, on September 7-10. Sponsored by the National Science Foundation, the discussions will concern the broader objectives of astronomical instruction as well as planetarium techniques. Registration is limited to 95 persons; additional information may be secured from James A. Fowler, curator of education at the institute.

NEWS NOTES

TRANSITS OF VENUS PAST AND FUTURE

While few eyewitnesses of the transit of Venus in 1882 are alive today, many younger readers will be on hand to observe the next passage of that planet across the disk of the sun on June 8, 2004.

A listing of 82 transits of Venus between 3000 B.C. and A.D. 3000 is given by Jean Meeus in the *Journal* of the British Astronomical Association for April, 1958. His extensive calculations were based upon the convenient tables of Venus published by H. P. Bhatt in India in 1957.

Mr. Meeus finds that on the average there are 13.7 transits of Venus per 1,000 years, the actual number varying between eight and 18. Transits can take place only during the first half of December or the first half of June, and when Venus is at the ascending or descending node of its orbit. Since the transit of June, 1518, the intervals between consecutive passages of Venus across the sun are 8, 105½, 8, and 121½ years; a transit is followed 243 years later by a very similar one.

The next four transits will take place on June 8, 2004; June 5-6, 2012; December 11, 2117; and December 8, 2125. Mr. Meeus calls attention to several future grazing transits. That on December 13, 2611, will be partial for the northern part of the Atlantic Ocean and western Europe, and complete elsewhere.

NEW ASSOCIATE DIRECTOR AT GRIFFITH OBSERVATORY

On July 1st, Dr. Robert S. Richardson became associate director at the Griffith Observatory and Planetarium in Los Angeles, California. He had been a member of the staff of Mount Wilson Observatory since 1930, and is well known for his observations of the sun and Mars. He is a prolific writer on astronomical subjects; among his books is *Exploring Mars,* published in 1954.

SHAPE OF THE EARTH

The earth appears to be slightly less flattened at the poles than was previously accepted, according to calculations by H. G. Hertz and M. Marchant, of the U. S. Army Map Service. Their conclusion is based upon changes in the orbits of artificial satellites; the more oblate the earth, the faster are the shifts of a satellite's perigee point and its ascending node.

According to their preliminary results, reported in *Harvard Announcement Card* 1408, the polar diameter of the earth is 26.57 miles shorter than the equatorial diameter, as deduced from the nodal shift of satellite 1958β2. This corresponds to an oblateness (diameter difference divided by equatorial diameter) of 1/298.38. The generally accepted value has been 1/297.0, giving a diameter difference of 26.70 miles.

Other calculations by Drs. Hertz and Marchant, based on the perigee of the same satellite and on the perigee and node of 1958α, agree in showing a smaller oblateness than 1/297.0.

The Army Map Service scientists emphasize the preliminary nature of their computations, for which Naval Research Laboratory orbit data were used rather than the original observations.

WALTER BAADE RETIRES

On June 30th, an outstanding authority on galaxies retired from the staff of Mount Wilson and Palomar Observatories after 27 years of service. Walter Baade gained world fame by two astronomical discoveries of the first importance. One was the recognition that there are two distinctive types of stars, Populations I and II, in our own and other galaxies. The other finding, announced in 1952, was that the cosmic distance scale needed a major revision, putting all extragalactic objects at least twice as far from our Milky Way galaxy as previously believed.

Recent projects of Dr. Baade included a collaboration with Rudolph Minkowski in the identification of cosmic radio sources with optically observed objects.

Dr. Baade, who is 65 years old, was born and trained as an astronomer in Germany. He joined the staff of the Hamburg Observatory in 1919, where he became well known for his discoveries with the 39-inch reflector of comets, asteroids, variable stars, and clusters of galaxies.

IN THE CURRENT JOURNALS

LUNAR TRAJECTORY MECHANICS, by Louis G. Walters, *Navigation,* Spring, 1958. "Navigation studies require consideration of all factors which serve to determine the course of the vehicle relative to that of the Moon, and the use of mathematical techniques which will lead to a precise end point."

GLOBULAR STAR CLUSTERS, by Helen Sawyer Hogg, *Journal* of the Royal Astronomical Society of Canada, June, 1958. "Globular clusters are dynamically so stable, so little affected by any disruptive forces, that their individual stars will die as stars before the clusters disintegrate as clusters."

CLIMATE AND THE CHANGING SUN, by Ernst J. Opik, *Scientific American,* June, 1958. "We know that the climate of the earth has in fact changed drastically over the eons of time. Many theories have been offered to explain these long-term swings: dust clouds from volcanic explosions, changes in the tilt or orbit of the earth, and so on. None of them has proved convincing. In the end we always come back to the simplest and most plausible hypothesis: that our solar furnace varies in its output of heat."

Amateur Astronomers

47th AAVSO Spring Meeting

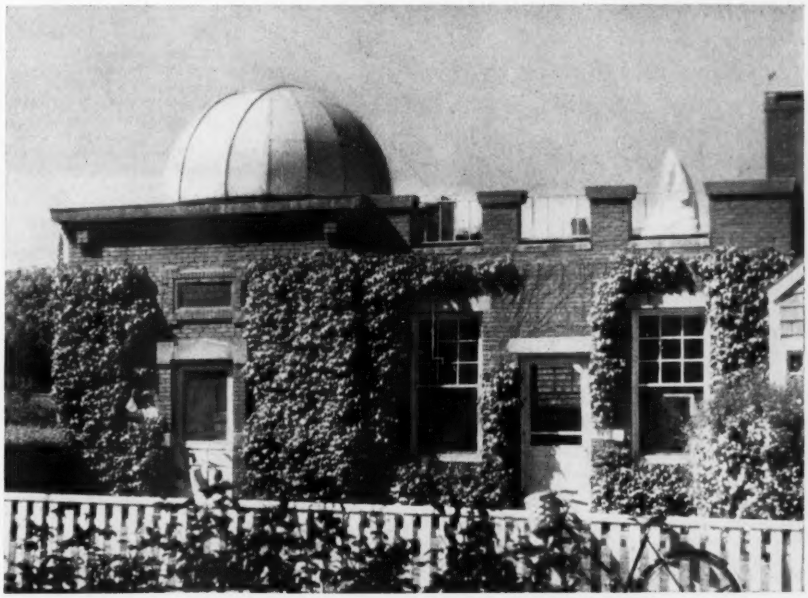
AFTER a rainy Friday, clear skies prevailed for the spring meeting of the American Association of Variable Star Observers on the island of Nantucket, Massachusetts, on June 12-15. The occasion was part of the 50th anniversary celebration of Maria Mitchell Observatory, the meeting being held by invitation of the director, Dr. Dorrit Hoffleit.

On Friday, June 13th, Dr. Edward Lilley, of Yale University Observatory, spoke on "Rockets, Radio, and Astronomy." Committee reports and talks by members were heard Saturday morning in the Maria Mitchell Association's scientific library, across the street from the observatory.

In the first of two quarterly reports since the 1957 fall meeting, Mrs. Margaret W. Mayall, AAVSO director, published 55,000 observations of 668 variable stars by 133 observers; in the second, there were 61,500 observations of 734 stars by 149 observers. The first such quarterly report, in 1946, listed only 407 variables.

The highlight of Saturday afternoon was an address by Margaret Harwood, who was the director of Maria Mitchell Observatory for over 40 years, gaining fame for her extensive photographic studies of variables in the Scutum star-cloud. Miss Harwood has also participated in a number of eclipse expeditions, leading one herself from Nantucket in 1932.

As the early part of Saturday night was occupied by the banquet (attended by 103 persons) and another session for papers, observing with the 5½-inch refractor did not begin until late. With the sky perfectly clear, planets and variables were viewed; meteors were counted; a fine aurora was seen; and, finally, the rocket of Sputnik III was watched in a 3:17 a.m. (EST) passage, when several accurate fixes on it were obtained.



The Maria Mitchell Observatory has a 7½-inch photographic refractor, mainly used for the investigation of faint variable stars. From a Kodachrome by J. E. Welch, West Springfield, Massachusetts.

NEW CLUB IN ALABAMA

The Tri-Cities Astronomy Club of Florence, Sheffield, and Tuscumbia, Alabama, was started by four amateurs last August, and now has 11 members. Telescope making and observing are emphasized at the informal meeting held at a member's home on the fourth Wednesday of each month. The club planned to sponsor a telescope making class this summer.

Each member possesses at least one telescope, and the club has 15 in all, ranging from a 1½-inch refractor to a 10-inch reflector. Instruments made by the group include a 10-inch Springfield, an 8-inch rich field, six 6-inch reflectors, and two Dall-Kirkhams — a 3-inch and a 4-inch.

Membership is open to all interested persons, who should communicate with the president, Roy May, 606 River Bluff Dr., Sheffield, Ala.

Each of these 11 Alabama amateur astronomers, all members of the Tri-Cities Astronomy Club, is seen standing alongside his own instrument.

MOUNTAIN STATES MEETING

The fourth annual convention of the Mountain Astronomical Research Society, a region of the Astronomical League, will be held on August 9th at the University of Denver in Colorado. The host is the Denver Astronomical Society.

MID-STATES CONVENTION

The Wichita, Kansas, Astronomical Society is the host for the Mid-States regional convention of the Astronomical League on August 30-31. The meeting will be held on the campus of the University of Wichita in air-conditioned buildings. On Sunday, August 31st, the afternoon session is for junior astronomers; the banquet is scheduled that evening.

THIS MONTH'S MEETINGS

Dallas, Tex.: Texas Astronomical Society, 8 p.m., home of E. T. Cramer, 5807 Gramercy Place. August 25, field meeting.

Edinburg, Tex.: Magic Valley Astronomical Society, 8 p.m., Pan American College Observatory. August 15, observing Saturn.

Palo Alto, Calif.: Peninsula Astronomical Society, 8 p.m., Palo Alto Junior Museum. August 1, Dr. V. Rossow, Ames Aeronautical Laboratory, "Table-top Experiments in Magnetohydrodynamics."

OBSERVER'S PAGE

Universal time is used unless otherwise noted.

Filter Techniques for Planetary Observers

COLOR FILTERS are of great value to the planetary observer. They help overcome image deterioration caused by scattering in the planet's atmosphere and in the earth's, as well as by atmospheric prismatic dispersion. They permit separation of the light from different levels in the planet's atmosphere, and they increase hue contrast between areas of differing color. Finally, they help reduce irradiation in the observer's eye.

All of these functions of filters concern, in a rather intricate manner, the sharpness of surface and cloud detail that is seen on a planet. For simplicity let us consider each factor separately.

Scattering interposes a luminous veil between the observer and his subject. The first quantitative study of the laws of atmospheric scattering was made in 1871 by Lord Rayleigh. He showed that for particles of a given size the scattering is inversely proportional to the fourth power of the wave length of the light. Hence, violet light of 4000 angstroms is scattered about 16 times more than deep red light of 8000 angstroms; the blueness of the daytime sky is the result of this property.

Rayleigh's law also holds approximately for the atmospheres of Mars and Venus. Here the filter comes to our aid, for with a suitable one we can eliminate the scattered blue light and observe planetary markings in red and yellow.

Prismatic dispersion by our atmosphere is most evident when a star or planet is seen near the horizon. It results from refraction being less for longer wave lengths; each point source spreads into a tiny vertical spectrum, the red end appearing nearer the horizon. This effect can be reduced by observing through a filter transmitting only a narrow spectral region.

Atmospheric penetration. To explore a terrestrial-type atmosphere to various depths, molecular scattering can be exploited. Since the shorter wave lengths are scattered more, it follows that ultraviolet light scarcely penetrates an atmosphere at all, violet light penetrates to some depth, blue still deeper, while blue-green may reach the solid surface. Filters applying these criteria can be used, for instance, in studying Martian atmospheric phenomena.

Hue contrast is affected by sharpness of boundaries and by differences in color and shade. Light yellow and orange filters are useful in judging the colors of the low-hue cloud belts and zones on Jupiter and Saturn. To bring out a white area on a reddish background, a green filter is useful. For example, a light yellow-green filter will sharpen the boundary of a white frost area on Mars by darkening the ochre desert, while allowing adequate penetration of the Martian atmosphere. A blue-green filter will similarly increase the contrast of an atmospheric cloud above an ochre desert region.

Irradiation occurs between adjoining areas of unequal brightness. The amount the bright area appears to encroach upon the fainter one is approximately proportional to their intensity difference. This is evidently a physiological effect, originating within the eye itself. Some astronomical examples are the apparent enlargement of the Martian polar caps and of Venus' cusp caps, and the apparent reduction in size of canals and dark spots on Mars. In photography, there is an analogous spreading of bright images in the emulsion.

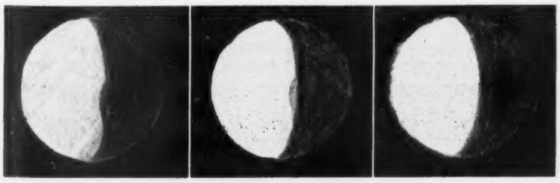
Some solar system objects display dark lines against a light background, for example, lunar rills and the narrow Martian canals. Irradiation causes these dark features to shrink, and sometimes to disappear completely.

Wratten Filters

No.	*Color*	*%*	*Dom.*	*Extreme Range*
8	Light Yellow	83	5720	4600 - 7000
12	Yellow	74	5760	5000 - 7000
15	Deep Yellow	66	5790	5100 - 7000
21	Orange	46	5890	5400 - 7000
23A	Orange-Red	25	6030	5700 - 7000
25	Red	14	6150	5900 - 7000
29	Deep Red	6	6320	6100 - 7000
38A	Blue	17	4790	4000 - 6400
39*	Dark Blue	1	4510	4000 - 5100
47B	Deep Blue	1	4800	4000 - 5000
48A	Deep Blue	1	4580	4000 - 5100
57	Yellow-Green	32	5360	4600 - 6200
64	Blue-Green	25	4970	4000 - 5900
70	Deep Red	⅓	6760	6500 - 7000
82A	Light Blue	72	4770	4000 - 7000

*Glass filter

The Eastman Kodak Wratten filters listed in the table have useful transmission characteristics for planetary work, are fairly stable, and have given good results. Most Wratten filters are made of gelatin, stocked in 2- or 3-inch squares, which may be cut to size and mounted in adapters to go over the eyepiece, as shown by the author's stock of filters in the ac-



Venus on August 26, 1954, drawn by W. E. Shawcross, with a 12½-inch reflector at 202x. Left to right: blue Wratten filter 47, green 58, and red 25.

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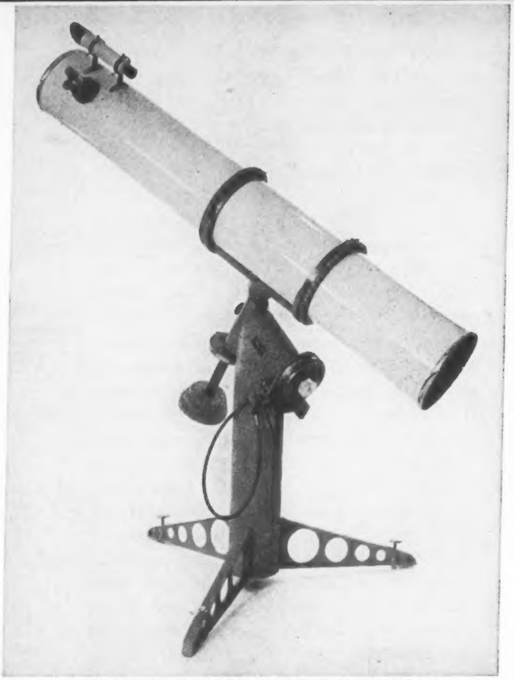

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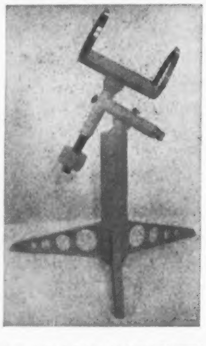

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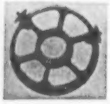

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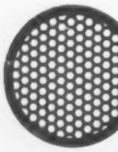

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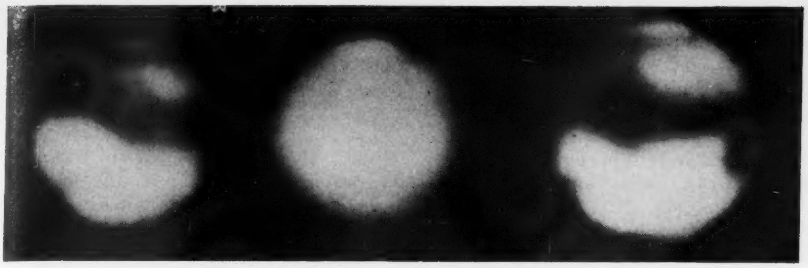


The center picture of Mars was made in blue light, the other two in orange, by L. J. Wilson on July 21, 1939, at 6:08, 6:12, and 7:10 UT (left to right) with a 12-inch reflector and eyepiece projection. The reproduction enlargement is about 12 times.

companying picture of his filter setup.

The columns in the table are Wratten number, general color characteristic, overall percentage of light transmitted by the filter in the wave-length region 4000 to 7000 angstroms, dominant transmission wave length, and approximate range of transmission within the same spectral region.

Filters can be used with eyepieces of any power, but since irradiation is less with fainter images, high magnifications help reduce it. If the quality of the seeing permits, a power of 40 per inch of aperture for reflectors and 30 per inch for refractors is recommended as a minimum for observing the moon, Mercury, or Mars. Somewhat higher powers are necessary to lessen irradiation on the disk of Venus, and a neutral density filter or partially crossed polarizers may be used in addition.

Color filters of low transmission heighten contrast of surface detail or clouds and at the same time cut irradiation. For instance, blue and violet filters 39, 47B, and 48A are useful for the low-contrast shadings of Venus because of the yellowness of these markings. Red, yellow, and green filters generally disclose little detail, but there is apparently an alternating color change from red to blue in the south polar region of Venus. There I have seen dark shadings with the aid of the low-transmission red filters 25, 29, and 70 (useful only with large telescopes); also with green 64. For dazzling lunar detail, filters 15, 21, 23A, or 57 are recommended.

Charles F. Capen's Wratten filters are stored in this box, where their characteristics are conveniently listed. The filter holder, lower left, fits over the eyepiece, being secured with a screw on its side. To its right are parts of a polarimeter.

Using the less-scattered yellow and red wave lengths gives an image with increased definition and contrast. Most of the scattered blue light in Mars' atmosphere may be filtered out with a deep yellow or orange filter (15, 21, or 23A); these also reduce the light from the blue and green areas, darkening the maria, oases, and canal markings in comparison with the orangish desert regions of the planet. A lighter yellow filter (8 or 12) will stop the scattered blue light also, but will allow passage of more green light from the maria.

On the other hand, a red filter (25 or 29) transmits red and some yellow light, but cuts out all blue and green, thus giving maximum contrast. A filter redder than 29 will probably cause a loss of very fine detail.

Techniques for observing planetary atmospheres usually require blue-transmitting filters, but their uses vary widely. For instance, only a very light blue filter with high transmission, such as 82A, would be used with a filar micrometer in determining the latitudes and longitudes of faint Jovian and Saturnian cloud and wisp formations.

On the other hand, to restrict observations to the top of Mars' atmosphere, rather dense deep blue filters would be used (39, 47B, or 48A); these sharpen the boundaries of high-lying clouds. With a lighter blue filter whose transmission band is shifted toward the green, as 38A, a deeper penetration may be made and any increase or decrease in cloud dimensions observed. Finally, a blue-green filter (64) may be employed for further cloud comparisons directly above the planet's surface.

Sometimes it is difficult to determine whether a Martian white area is a high-altitude cloud, a low-lying one, or a

frosted ground area. If the white patch lies in an ochre desert region, make comparative observations with yellow-green (57) and deep blue (47B). If the cloud is larger, brighter, or better defined with filter 57, it probably lies near the surface, but should be high-altitude if 47B gives a superior view.

Most of Mars' yellow-type clouds seem to be close to the surface, on the basis of these tests. Martian cloud studies are of definite value in ascertaining meteorological conditions on the planet.

One puzzling phenomenon of Mars is the "blue clearing." When this occurs, surface features can be photographed and seen in blue light for approximately a 10-day period, roughly centered at the date of opposition to the sun. But the phenomenon is quite variable, and not enough is known about it to predict its occurrence. Therefore, observations of its appearance and disappearance are important. For this purpose, compare surface features seen through yellow and red filters (15, 21, 25) with detail observable through blue filters (38A, 39, 47B, 48A).

Filters can also disclose daily changes in the Martian atmosphere near the poles. A polar hood of haze is seen to vary in extent and density from night to night but is detected only in blue and green light. Red light apparently penetrates the hood and clearly shows the surface markings beneath. These facts have been verified photographically as well as visually.

For those who wish to try filter photography of the planets, the following are recommended emulsion-filter combinations: red light, 103-E, 29F; yellow light, 103-G, 12; blue light, 103-O, 47.

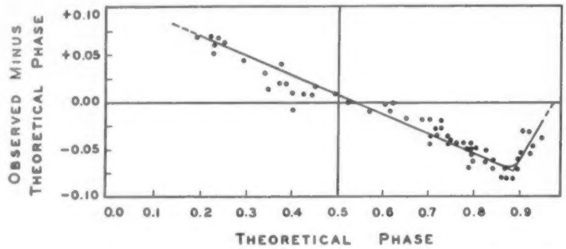
CHARLES F. CAPEN, JR.
New Mexico College of Agriculture and Mechanic Arts

PHASES OF VENUS

Observers of Venus have often noticed that the actual phase of that planet departs from prediction. When Venus is in the morning sky, near the time of greatest western elongation, its waxing disk becomes half illuminated as much as a week later than the predicted time. In the evening sky, the planet attains this phase (dichotomy) earlier than would be expected. These anomalies have been extensively observed by members of the Association of Lunar and Planetary Observers and of the British Astronomical Association.

An important discussion of this phenomenon has appeared in a recent Russian book by V. A. Bronshtein, *Planets and Their Observation*. He summarizes work by two Russian amateurs, N. N. Michelson and V. N. Petrov, who measured a large number of drawings of Venus. Their results are shown in the diagram reproduced here. The horizontal scale is the phase of Venus (illuminated fraction of the apparent disk) as given by ephemerides; the vertical scale is the difference: observed phase minus theoretical phase.

Evidently the phase anomalies are not limited to the time of dichotomy (marked by a vertical line). Instead, Venus as a crescent in general appears broader than expected, and the gibbous planet narrower than predicted. Here is an effect worthy of further attention from amateur observers.



Deviations of the phase of Venus from theory, after N. N. Michelson and V. N. Petrov. From the book "Planets and Their Observation," by V. A. Bronshtein.

The Bronshtein text contains many other suggestions for the advanced amateur who is interested in planetary work. It is in the Russian language, having been published at Moscow in 1957 by the State Publishing House of Technical Theoretical Literature. This little volume of some 200 pages deserves translation into English.

JUNE 6-7 AURORA

A bright aurora was seen at widely scattered places on the night of June 6-7. Reports were received from Manson, Iowa; Kingsport, Tennessee; Pittsburgh, Pennsylvania; Schenectady, New York; Chicago, Illinois; and Newport, Rhode Island. This photograph was taken at Pittsburgh by W. A. Feibelman, just when the display had its maximum intensity, at midnight daylight saving time.

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SKY AND TELESCOPE BACK ISSUES

Unless otherwise specified, the previous numbers of *Sky and Telescope* to which references are made in articles and departments are available at 50 cents per copy. Since January, 1955, only the issues of January, February, October, and November, 1956, and that of January, 1957, are out of print. Many issues before January, 1955, are available; write for information on particular copies.

A few bound sets of Vol. XV (November, 1955, to October, 1956) and Vol. XVI (November, 1956, to October, 1957) are available, in blue library buckram, at $12.50 each volume, while the supply lasts.

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BOOKS AND THE SKY

THEORETICAL ASTROPHYSICS

V. A. Ambartsumyan, editor. Pergamon Press, New York, 1958. 645 pages. $22.50.

SOME YEARS AGO there was a persistent rumor of a Russian text on theoretical astrophysics written by V. A. Ambarzumian. This book was revised and rewritten in 1952, appeared in German, and now has been translated into English by J. B. Sykes. It gives a very extensive summary of the Russian contributions to astrophysics, and for that reason alone is valuable, particularly to those of us unfamiliar with Slavic languages. The reader with a thorough background in classical and atomic physics will be able to read the entire volume with profit.

This is the standard text for Russian graduate students in astrophysics. They evidently come to the subject with a good background in physics and mathematics, equivalent to that obtained in an undergraduate major in a first-rate physics department.

The first two-thirds of the book, written by E. R. Mustel, deals with the sun and stellar atmospheres. The transfer equation is treated mostly from the point of view of the Eddington approximation, little use being made of exponential integral functions. Ambarzumian's own powerful principle of invariance is not presented until Chapter 33. Chapter 8, which discusses the validity of the approximations of thermodynamic equilibrium and Mustel's method of handling the nongray stellar atmosphere, deserves special mention.

The formation of the Fraunhofer lines is treated in Part II, where we read, "The assumption that the chief mechanism which determines the formation of absorption lines is the scattering of radiation is confirmed by observations and a more detailed analysis of conditions existing in stellar atmospheres." The old argument about the nondisappearance of the Fraunhofer lines at the limb is cited as proof of the mechanism of scattering. No mention is made of the alternative hypothesis that there is a sharp temperature drop near the surface of the sun (extreme deviations from the gray-body temperature distribution near the surface as a consequence of the blanketing effect), nor of the fact, well established by high-dispersion spectrograms of the sun taken under conditions of good seeing, that the centers of the strong Fraunhofer lines are all formed in the chromosphere.

But the theoretical work on the temperature distribution in the upper photosphere, particularly by K. H. Böhm at Kiel, and the studies of the center-to-limb variations of the cores of strong Fraunhofer lines at the McMath-Hulbert Observatory, demonstrate that the mechanism of absorption appears capable of explaining the observed behavior of the dark-line spectrum of the sun. Scattering may exist, but the so-called proofs that true absorption does not occur in the dark lines are not convincing. At the present time this question is unsettled.

Chapter 18, devoted to solar electrodynamics, introduces a subject that is certain to play an ever-increasing role in theoretical astrophysics. The nature of the boundary conditions makes the problems of extraordinary difficulty, and few quantitative results have been attained. There is an extensive and stimulating discussion of the outer layers of the sun, the field in which Shklovsky, Vyazanitsyn, and Severny have made important contributions. However, the reader familiar with the literature of the chromosphere and corona will find a number of important subjects and points of view treated rather inadequately or not at all.

There are three chapters devoted to planetary nebulae. Although the theory of radiation pressure is discussed, there is no mention of Olin Wilson's fundamental observations on the kinematics of these objects. The discussion of novae appears to be adequate, the section on bright-line stars contains much valuable material, and the brief account of stellar associations is well done. The reviewer regrets the brevity of the section on interstellar matter, where he is surprised to read that the 21-cm. line was detected by Ewen and Purcell in Australia.

The section on stellar interiors is perhaps the most controversial part of the book. The treatment postulates homogeneous stars and asserts that "there is no reason to suppose that the chemical composition inside the stars differs markedly from the composition of stellar atmospheres, since there is strong mixing." Further on we read that "contemporary theory has not yet given a satisfactory explanation of the sources of energy in giant stars."

Shell-source models for giant stars and the whole modern theory of stellar evolution based on them are not mentioned. A model of the sun is presented, using the carbon cycle, since the proton-proton reaction as described in the text is inadequate to supply the requisite amount of energy.

On the observational side of the picture, the assertions are made that the luminosity of a subdwarf is a known function of its mass and radius and that the luminosity of a giant shows a well-defined dependence on its mass.

If *Theoretical Astrophysics* appears provincial in spots or even downright biased, one must remember that this defect is no monopoly of the Russians. If they appear at times to have neglected western viewpoints and contributions, we of the West have sometimes overlooked Russian work. This neglect was not intentional; it is the result of a language

barrier. We owe a debt of gratitude to the translator for breaking through this barricade to bring us the fundamental contribution of Ambarzumian and his colleagues in their own words.

LAWRENCE H. ALLER
University of Michigan Observatory

THE PRESENT AND FUTURE OF THE TELESCOPE OF MODERATE SIZE

Frank Bradshaw Wood, editor. University of Pennsylvania Press, Philadelphia, 1958. 219 pages. $5.00.

SELECTED HIGHLIGHTS in the fields of photometry, astrometry, and spectroscopy are presented in this collection of 14 papers originally delivered at a symposium held in connection with the June, 1956, dedication of the Flower and Cook Observatory, University of Pennsylvania (*Sky and Telescope*, September, 1956, page 480).

By "telescope of moderate size" is meant one between 12 and 40 inches aperture, although researches with instruments from 2½ to 82 inches are reported. The scope of the book is more ambitious than the title suggests, for much of the subject matter applies to larger telescopes as well. Nor is this a compendium of the uses of moderate-sized telescopes; rather, it gives a few well-chosen and stimulating applications. Special-purpose instruments such as solar telescopes are not considered.

Underlining the importance of electronic techniques in astronomy, most of this book forms a useful wide-range supplement to *Astronomical Photoelectric Photometry* (1953), also edited by F. B. Wood. Among the electronic developments now described, photoelectric image-forming devices promise, for the near future, a considerable gain in telescope efficiency in many applications by employing the most advanced photon detectors available. A. Lallemand has used photocathodes with electron optics and electron-sensitive plates for image storage, to surpass greatly the speed of ordinary photography. But we still need a practical system for image conversion that can be applied in a routine fashion.

Here and elsewhere there has been an unfortunate tendency to describe anticipated improvements in terms of telescope size, for example, "such-and-such a device will allow a 20-inch telescope to reach the limiting magnitude of the 200-inch." Not properly qualified, such statements can be misleading.

Apropos the application of small telescopes to photoelectric problems, G. E. Kron uses an apt simile — "If the large telescopes are like Percherons, then the small telescopes must be like race horses. For best performance, they must be carefully groomed and cared for. . . ." Two papers on photoelectric photometry indicate how automation in obtaining and processing data provides some of this grooming. Two systems are described for recording photoelectric data in a form suitable for analysis by modern computing machines. Photometrists are now exploiting these machines, used so effectively in some other astronomical applications.

A completely automatic system, which could carry out a photoelectric observing program from telescope setting to the final results in printed form, apparently is within our present technological capabilities. Automation is already a feature of instruments used in high-altitude balloons, rockets, and satellites.

Modern infrared techniques in photometry are dealt with, as well as photoelectric studies of scintillation. The latter not only provide unique information about the upper atmosphere, but have considerable practical importance for the many astronomers who cannot send equipment into space.

Further chapters are concerned with astrometry, a field in which small and moderate-sized telescopes are still unrivaled. B. S. Whitney points out the great importance of continuing photographic observations of variable stars with modest equipment; in no field is continuity of observation more important. The large amount of spectrographic work still to be done with instruments of about 40-inch aperture is stressed by D. B. McLaughlin.

ARTHUR A. HOAG
U. S. Naval Observatory
Flagstaff Station

NEW BOOKS RECEIVED

La Photographie Astronomique, *Gerard de Vaucouleurs,* 1958, *Editions Albin Michel,* 22 Rue Huyghens, Paris 14, France. 128 pages. 690 fr, paper bound.

The history of astronomical photography, from the first daguerreotype of the moon taken 120 years ago to the latest image-converter techniques, is told by a leading French astronomer, now at Harvard.

Other Worlds in Space, *Terry Maloney,* 1958, *Sterling.* 128 pages. $2.95.

The author gives an easy-to-understand account of our neighbor planets, and accompanies his text with some imaginative color paintings and drawings.

Structure and Evolution of the Stars, *Martin Schwarzschild,* 1958, *Princeton University Press.* 296 pages. $6.00.

An outstanding Princeton astrophysicist presents a technical account of present knowledge concerning stellar interiors and evolution. He summarizes the enormous growth of these subjects since nuclear physics was introduced into astronomy about a decade ago.

Frontiers in Science, *Edward Hutchings, Jr.,* editor, 1958, *Basic Books.* 362 pages. $6.00.

Among 35 popularly written essays on present-day scientific research are seven dealing with astronomy. Such fields as cosmic rays, the life cycles of stars, and the size of the universe, are treated. The contributors include leading biologists, physicists, and astronomers.

Comparison of the Large-Scale Structure of the Galactic System with that of Other Stellar Systems, *N. G. Roman,* editor, 1958, *Cambridge University Press.* 72 pages. $3.00.

This volume is a report of the fifth of the International Astronomical Union's 1955 symposia. It gives the English text of 16 papers presented at the meeting in Dublin, on the general theme of optical and radio studies of our own and other galaxies. The Magellanic Clouds, supernovae, spiral structure, and multiple galaxies are among the topics treated. The book also contains some material not given at Dublin.

1001 Questions Answered About Astronomy, *James S. Pickering,* 1958, *Dodd, Mead.* 420 pages. $6.00.

Beginning with "What is the sun?" the amateur will find 1,048 other questions and answers on astronomy in the 15 sections of this book. There are many short biographies.

Planetary Co-ordinates for the Years 1960-1980, 1958, *Her Majesty's Stationery Office,* York House, Kingsway, London W. C. 2, England. 160 pages. £1 10s.

Heliocentric longitudes and latitudes of the planets from Mercury through Pluto are listed to 0.001 degree for the years 1960 to 1980, together with rectangular co-ordinates and similar data. The tables, prepared by H. M. Nautical Almanac Office, are particularly intended for computers of the perturbations of asteroids and comets. An appendix contains formulae and other data for calculators.

In arrangement, the volume closely resembles its two predecessors, published in 1933 and 1939, containing planetary positions for 1800-1940 and 1940-1960. The series has many less technical uses, for example, in the construction of scale diagrams of planetary orbits.

A Handbook of Space Flight, *Wayne Proell* and *Norman J. Bowman,* 1958, *Perastadion Press,* 10630 S. St. Louis Ave., Chicago 43, Ill. 458 pages. $8.00.

This second edition is a substantial revision of the 1950 version; the number of pages is more than doubled and the scope has been expanded. In tabular and graphic form, the book provides data on such diverse fields as properties of materials, physical constants, the earth's atmosphere, albedos of the planets, rocket fuels, and radiation shields. A glossary of rocketry and astronautics terms is included, together with long lists of references.

The Russian Literature of Satellites, Part I, 1958, *International Physical Index, Inc.,* 1909 Park Ave., New York 35, N. Y. 181 pages. $10.00, paper bound.

The Soviet journal *Progress in Physical Science* devoted its September, 1957, issue to artificial satellites and astronautics. Six of its articles are here made available in English translation. Mathematical in character, they deal with technical aspects of satellite orbit theory, and with the dynamics of flight to the moon.

Atmospheric Explorations, *Henry G. Houghton,* editor, 1958, *Wiley.* 125 pages. $6.50.

To honor Benjamin Franklin 250 years after his birth, the American Academy of Arts and Sciences held a symposium on atmospheric electricity and the upper atmosphere, subjects in which Franklin was much interested. This book contains the five semi-technical summaries presented on that occasion, dealing with such topics as cloud electrification, lightning, and radio scattering in the ionosphere. The Technology Press of Massachusetts Institute of Technology is a copublisher.

The Exploration of Space by Radio, *R. Hanbury Brown* and *A. C. B. Lovell,* 1958, *Wiley.* 207 pages. $6.50.

Surveying the new field of radio astronomy, this book reviews its history, describes its techniques and instruments, and discusses its uses in studying the sun, moon, meteors, and the galaxy. Both authors are radio astronomers at the University of Manchester, and Dr. Lovell is director of its Jodrell Bank Experimental Station.

Concepts of Classical Optics, *John Strong,* 1958, *W. H. Freeman and Co.,* 660 Market St., San Francisco 4, Calif. 692 pages. $9.50.

A Johns Hopkins physicist describes both geometrical and physical optics in a new college textbook. He also devotes many pages to recent developments in such fields as radiation detectors, measuring the velocity of light, and fiber optics.

Of Stars and Men, *Harlow Shapley,* 1958, *Beacon Press.* 157 pages. $3.50.

The former director of Harvard Observatory presents his ideas on the place of living things in the universe as revealed by modern astronomy.

A Guide to Astronomy, *Lloyd Mallan,* 1958, *Arco.* 132 pages. $2.00.

Another in a growing number of popularly written astronomy books for the beginner, this relies mainly on photographs to condense the subject into a few pages. A six-page picture story gives brief instructions for assembling a 3-inch refractor, while a similar layout proposes grinding and testing a 6-inch mirror.

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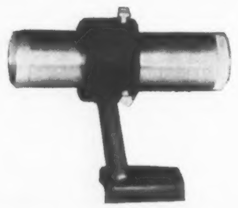

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The Neo-Brachyt Reflector

OFF-AXIS OPTICS make possible an ideal form of reflecting telescope for amateur use. With diffraction from the spider and the diagonal or secondary mirror eliminated, planetary definition and double star separation equal those of the best apochromatic refractors. This month we report the work of two amateurs who have built off-axis telescopes that use spherical optics for the two mirror surfaces.

The design is a modification of the *brachyt* reflector proposed in 1685 by the astronomer Johann Zahn. It was brought to its present form by Anton Kutter in Germany, who in 1953 described it in his book *Der Schiefspiegler* (The Oblique Reflector). This *neo-brachyt* design was introduced in this country by G. D. Roth and E. L. Pfannenschmidt in the *Strolling Astronomer's* December, 1952, issue (now out of print).

That article presented a version in which the negative astigmatism, inherent in this type of design, was eliminated by deforming the secondary mirror by pressure on its rear surface. The newer design, following Kutter, removes the astigmatism with a weak cylindrical lens placed a short distance inside the final focus.

F. Salomon's 8-inch neo-brachyt has a distinctive mounting, the mirror replacing the usual counterweight. The long opening beneath the upper end of the secondary's tube admits the oblique cone of light from the primary. The observer does not look in the same direction as the object, due to the inclinations of the mirrors.

Such an instrument has been constructed by F. Salomon, 3 Hechalutz St., Haifa, Israel, who writes:

"I have built an 8-inch off-axis instrument as described in *Der Schiefspiegler*. Its performance has been compared with that of my 8-inch f/10 Newtonian (*Sky and Telescope*, February, 1953, page 110).

"The new telescope operates at f/20, giving an image brightness one quarter that of the Newtonian, but faint nebulae and clusters appear brighter because the sky background is practically black. With steady seeing under high powers, images of bright stars show two or three closed diffraction rings as in a refractor, without halo or crosses of diagonal and spider diffraction. Although the planetary images of the off-axis reflector are not crisper than those of the Newtonian, the greater contrast at low levels of illumination is noticeable.

"The oblique reflector is essentially a Cassegrainian, whose secondary is placed just out of the path of the light that falls on the primary. In instruments smaller than about nine inches, both mirrors are spherical and inclined to each other, the secondary bringing the final focal plane to a point away from and well behind the primary. One would expect the coma caused by the tilt of the mirrors to be less the smaller the tilt angle. But Kutter found that only a certain fairly large angle of tilt (which is easily calculated) eliminates coma entirely, though at the expense of incurring negative astigmatism. This aberration is then taken care of by the weak plano-convex cylindrical lens placed just inside the final focus. The regular Cassegrainian formulas still apply, with the separation between the two mirrors being equal to approximately seven diameters of the primary mirror.

"My convex secondary mirror does not have the same radius of curvature as the concave primary; it should have been fringe-tested against a matching surface. A fairly good figure for the secondary was obtained, however, by testing it through the back of the glass, which was turned on the test stand until a position was found where striae in the glass did not interfere. Colors were neutralized by a red filter in front of the pinhole light source.

"For the corrector, I used a simple plano-cylindrical spectacle lens of $1\frac{1}{2}$ diopters, placed $1\frac{1}{2}''$ inside the focus. The exact power does not matter very much, since the effect varies with distance from the focus. The lens is mounted in a $1\frac{3}{4}''$

tube 4" long, which slides in a bushing for adjustment. The focusing drawtube fits loosely over it, and an opening at the end gives access to the sliding tube.

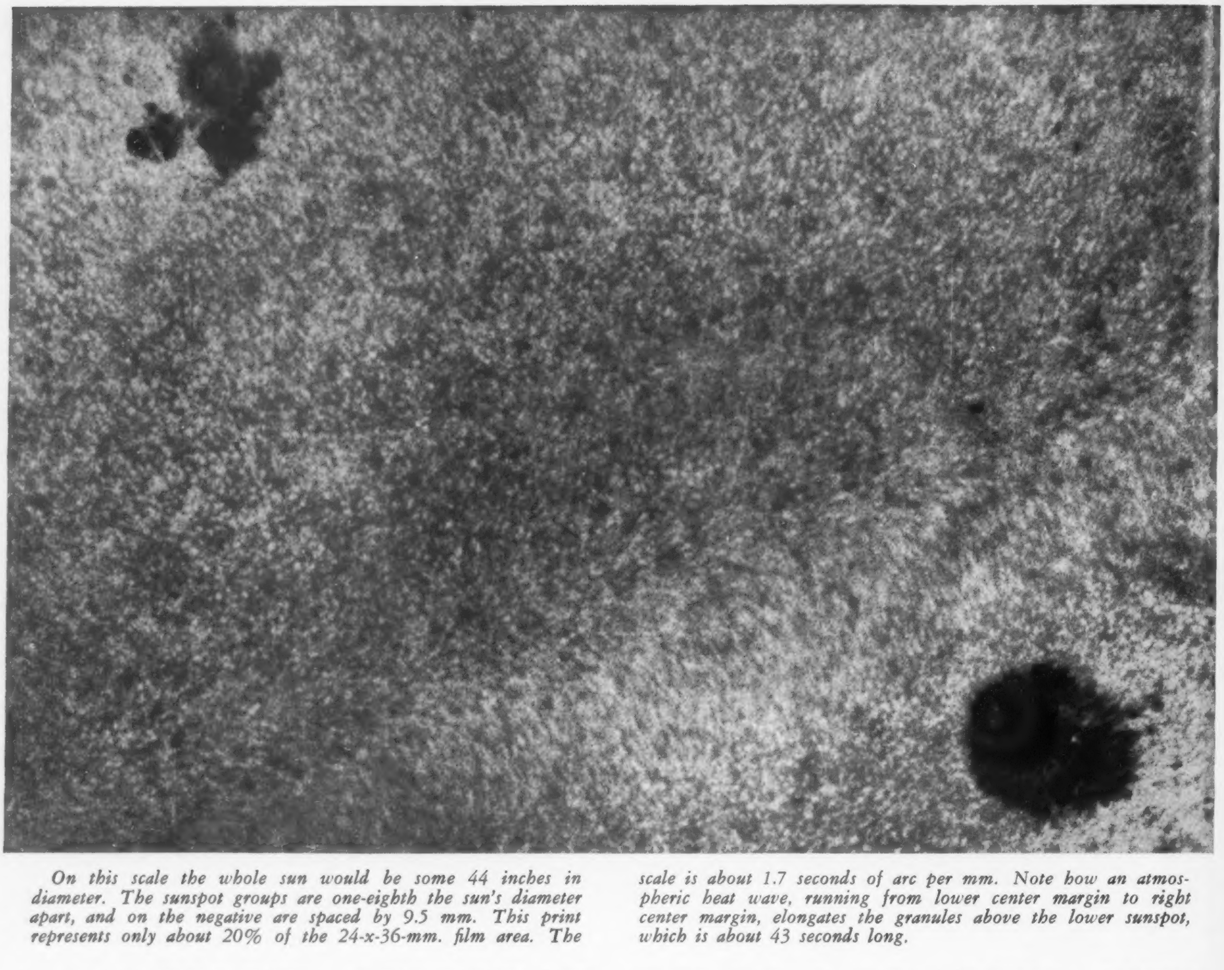
"Adjustment of the oblique reflector was as follows: In daylight the secondary mirror was viewed through a long tube, inserted in place of the eyepiece, with the cylindrical lens removed. The secondary was shifted and tilted until it was concentrically opposite the viewing tube and showed at the same time the whole primary mirror well centered. The primary was then tilted so that the secondary partially appeared in it, symmetrically on the line connecting the centers of both mirrors and, hence, partially silhouetted. The cell holding the primary mirror should have one of its adjusting screws on this central line, and the final daytime adjustment consisted of tilting the mirror until the secondary image just disappeared off the primary.

"At night I corrected astigmatism by viewing a not-too-bright star, such as Polaris, through a medium-power eyepiece, sliding and turning the cylindrical lens until the extrafocal image became absolutely round. It should be mentioned that traces of astigmatism may reappear with stars in other parts of the sky, when the eye looks through the eyepiece in a position different from that used for the adjustment.

"In this case the fault lies in the observer's eye, and during the adjustment he must wear glasses that neutralize his own astigmatism. With my f/20 instrument, even medium-focal-length eyepieces give plenty of eye relief, so it is never necessary to remove glasses while observing.

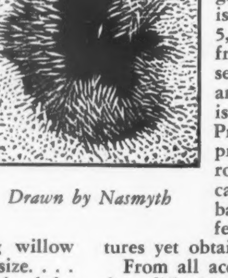
"After making these adjustments, I still found traces of coma, caused by small discrepancies between the calculated and the actual focal lengths of the optics, as well as by inaccuracies in the mounting. The coma was eventually remedied by tilting the primary farther away from the secondary. Had the coma disappeared only by tilting the primary toward the secondary, silhouetting would have resulted, and it would have been necessary to alter the distance between the two mirrors. Naturally, each tilt of a mirror requires readjustment of the cylindrical lens and the telescope view finder.

"Some time ago I made a new secondary, and after coma and astigmatism were neutralized I found that circular images looked slightly egg-shaped. This trouble was traced to the difference in focal length between the old and new secondaries. While this was only some 1½" to 2", it was enough to upset the relationship between the angles and the distances. Although one particular inclination of the primary gave freedom from coma, I was stuck with the distortion. On the other hand, a primary inclination that gave an image free from distortion reintroduced coma. Only after



On this scale the whole sun would be some 44 inches in diameter. The sunspot groups are one-eighth the sun's diameter apart, and on the negative are spaced by 9.5 mm. This print represents only about 20% of the 24-x-36-mm. film area. The scale is about 1.7 seconds of arc per mm. Note how an atmospheric heat wave, running from lower center margin to right center margin, elongates the granules above the lower sunspot, which is about 43 seconds long.

A 3.5-INCH QUESTAR PHOTOGRAPHS THE SOLAR GRANULATIONS FROM SEA LEVEL



Drawn by Nasmyth

"I think if we assign one year rather than another for the birth of the youthful science of solar physics, it should be 1861, when Kirchhoff and Bunsen published their memorable research on Spectrum Analysis, and when Nasmyth observed what he called the 'willow-leaf' structure of the solar surface. Mr. Nasmyth, with a very powerful reflecting telescope, thought he had succeeded in finding what these faint mottlings really are composed of. . . . The whole sun is, according to him, covered with huge bodies of most definite shape, that of the oblong willow leaf, and of enormous but uniform size. . . . 'These,' he says, 'cover the whole disk of the sun (except in the space occupied by the spots) in countless millions, and lie crossing each other in every imaginable direction.' "

So wrote Prof. Samuel P. Langley in 1891, while director of the Allegheny Observatory. His drawings of sunspot detail and granular structure, made with the 13-inch refractor there from 1870 on, are masterpieces of visual observation that have well withstood the test of time.

Nowadays the solar granules are ascribed to ascending and descending currents of gas in the solar atmosphere. Two recent articles in "Sky and Telescope" describe the problems involved in taking pictures of the granulations. In the May, '57, issue are good pictures taken at 5,862 feet with a 6.5-inch refractor, while samples of Janssen's work in the 19th century are included in the January, '58, issue, as part of an account of Project Stratoscope. In the latter project a 12-inch quartz-mirrored reflector with automatic camera, carried in unmanned balloon flights to above 80,000 feet, took the finest solar pictures yet obtained.

From all accounts it appears that tremendous difficulties are encountered by those who wish to see or photograph the granules. Their small size of 1 and 2 seconds of arc or less calls for unusually fine seeing, such as some mountaintops afford because they are above a large proportion of our heated air.

The photograph above was taken at sea level on May 25, 1958, at 1 p.m., E.D.T. at Sarasota, Florida, by Mr. and Mrs. Ralph Davis with their 3.5-inch De Luxe Questar. They used exposures of 1/1,000 second with 35-mm. microfile film in a Hexacon Supreme camera body, with eyepiece projection and a green war-surplus filter 40 mm. from the film plane. For the sake of fastest possible exposures, the patented Questar external filter was not used. To avoid heating, the instrument was capped until ready to expose.

The projected solar image was 3 inches in diameter, indicating an effective focal length of 330 inches, or 27.5 feet. When you consider that this is 55 times the 6-inch separation between Questar's lens and mirror, we submit that such performance from so small an instrument borders on the miraculous.

The De Luxe Questar sells for $995 as shown and $1100 with quartz mirror. Literature and time payment plan on request.

QUESTAR CORPORATION
New Hope, Pennsylvania

I had shortened the distance between the center of the primary and the secondary axis by some $\frac{3}{4}''$ could I eliminate both aberrations at the same time. This mechanical alteration could also have been achieved by shifting the whole secondary tube along the saddle, provided the eyepiece in the drawtube could still reach the focus.

"The mounting uses the primary mirror and its cell as a counterweight, as shown in the photograph of the telescope on page 529. This results in better stability than when all the optics are mounted on one side of the polar axis and a counterweight carried on a long shaft."

An American instrument of the same size has been built by Oscar R. Knab, 59237 S. Ironwood Rd., South Bend 14, Ind., who writes:

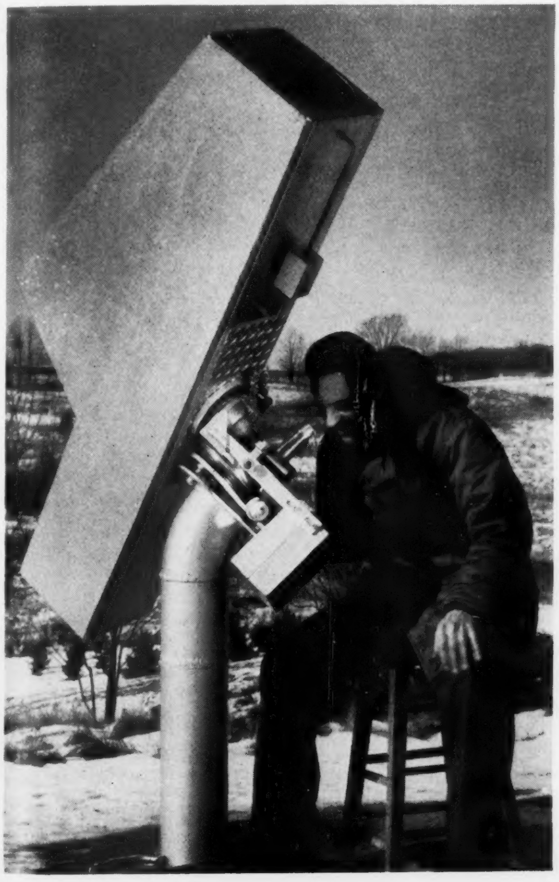
"I had long wanted to own a sizable refractor to avoid the diffraction and silhouetting in reflectors that spoil their definition. Since a refractor of 6- or 8-inch aperture is expensive, I decided upon an off-axis reflector.

"I made a full-sized layout from the *Strolling Astronomer* article, with the changes necessary for sending the secondary beam of light down the hollow declination axle of my Springfield mount (*Sky and Telescope,* December, 1954, page 71). With this type of mounting the optical system, which has an effective focal length of 160″, is placed in a tube only 4′ 6″ long. The tube is made from $\frac{1}{4}''$ exterior-grade plywood, with rabbeted oak rails and internal stiffener baffles; the entire unit is held together with glue and brass screws. Cradling the unit at its midpoint and balancing with a sliding weight on the upper end of the tube has permitted me to cut 21″ off my mounting pedestal. Thus I can sit rather than stand while observing.

"My 8-inch f/12 concave primary and 4-inch f/24 convex secondary have the same radius of curvature, exactly 192″. In fact, Leroy Clausing corrected the convex surface by interference testing against the primary. The distance between the mirrors is approximately seven times the diameter of the primary.

"In front of the final focus is a small correcting lens that cancels the astigmatism; it is a convex cylinder of ordinary optical crown glass with a plane back, approximately $1\frac{1}{4}$ diopters power. It must be about $\frac{5}{8}''$ to $\frac{3}{4}''$ thick to bring the blue and yellow color bands to focus in the same plane. A local optical shop made mine for $3.00. As a lens so near the final focus need not be achromatic or very accurate, spectacle-lens tolerances are permissible except in very large instruments.

"I used a standard cell for the 8-inch mirror and made adjustable, spring-loaded aluminum cells for the 4-inch



Folding his 8-inch neobrachyt with an extra flat and using it as a Springfield instrument makes observing exceptionally convenient for Oscar Knab. Although this telescope, with three mirrors and a correcting lens, has many optical surfaces, definition is superb. The theoretical limit of resolving power is reached in good seeing. Note the counterweights, one on a sliding rod at the upper end of the tube, the other on the opposite side of the mounting from the tube. On the next page is a diagram of this instrument, with its design figures.

secondary and a 3-inch quartz diagonal. This flat, which intercepts the beam from the secondary and directs it down into the Springfield mount, has to be exceptionally good, as it works some distance inside the focus. Although both mirrors are spherical, they must have better-than-average surface smoothness or definition will surely suffer. Therefore, John McQuaid of Logansport, Indiana, made the primary mirror accurate to 1/25 wave for me.

"The photographic image of the moon at the final focus is 1⅜" in diameter. The visual definition on the moon is excellent and the absence of secondary diffraction is a blessing. On nights of good seeing it is possible to use the highest powers without the image breaking down.

"A certain amount of experience is needed to get full performance from a neo-brachyt. Like any other compound telescope, under high power it is rather sensitive to seeing conditions. It is good for terrestrial viewing, as there is no sky fog from daylight. An 8-inch is rather clumsy as a portable instrument, being less compact than a Maksutov or a conventional Cassegrainian."

Mr. Knab would like to correspond with others interested in neo-brachyt telescopes, and will be happy to answer any questions.

As our two contributors point out, the neo-brachyt seems to have much flexibility in construction. The Salomon design has primary and secondary mirrors of unequal radius, and uses a thin spectacle lens as a corrector. Mr. Knab makes the radius of the secondary the same as that of the primary and employs a thick correcting lens.

The formulas for angles $\mathbf{A}_1$ and $\mathbf{A}_2$, the tilts of the mirrors, are:

For the primary, $\sin 2\mathbf{A}_1 = \mathbf{S}/\mathbf{E}$, where **S** is the sum of the radii of the primary and secondary mirrors, and **E** is their separation.

For the secondary,

$$\sin \mathbf{A}_2 = \frac{(\mathbf{R}_2/\mathbf{R}_1^2)\sin \mathbf{A}_1}{(\mathbf{r}_2/\mathbf{r}_1)^3\,(1/\mathbf{R}_2 + 1/\mathbf{P})},$$

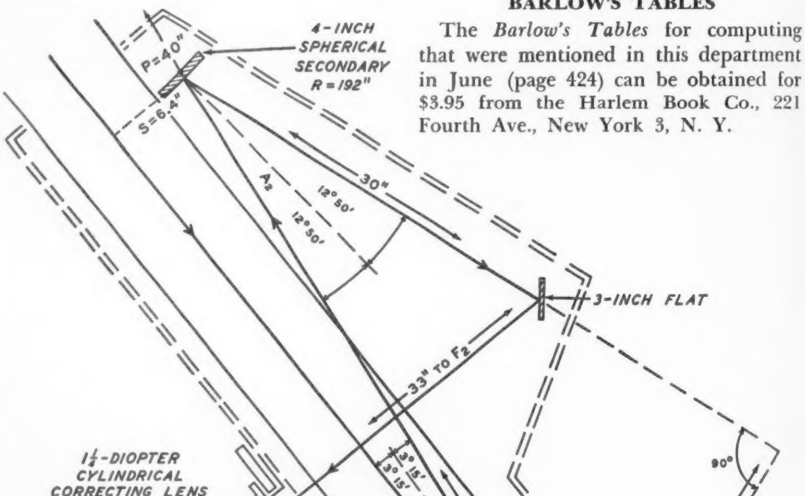
where $\mathbf{r}_1$ is the radius of the primary mirror, $\mathbf{r}_2$ the radius of the secondary, $\mathbf{R}_1$ the radius of curvature of the primary, $\mathbf{R}_2$ the radius of curvature of the secondary, and **P** the distance from the focus of the primary to the secondary mirror.

R. E. C.

ED. NOTE: Addresses for the authors mentioned above are: Anton Kutter, Biberach a.d. Riss, West Germany; Gunter D. Roth, Theodolindenstrasse 6, Munich 9, West Germany; E. L. Pfannenschmidt, General Delivery, Port Arthur, Ontario, Canada.

BARLOW'S TABLES

The *Barlow's Tables* for computing that were mentioned in this department in June (page 424) can be obtained for $3.95 from the Harlem Book Co., 221 Fourth Ave., New York 3, N. Y.



The doubled broken line represents the protective box containing the optical parts of the Knab telescope. Without folding the ray path, the secondary focus would be 63 inches from the convex secondary, well behind the primary mirror.

AIRSPACED OBJECTIVES

MOUNTED IN ALUMINUM CELLS f/15

We offer the lowest priced, hand-corrected, precision, American-made astronomical objective, *mounted in a black-anodized aluminum cell.* Our reputation has been established over the years as the most reliable source of high quality astronomical lenses.

"Those in the know" BUY FROM US BECAUSE:

Each lens is thoroughly tested by us and is guaranteed to resolve two seconds of arc or better. They are corrected for the C and F lines (secondary chromatic aberration). The zonal spherical aberration and the chromatic variation of spherical aberration are negligible. The cell is machined to close tolerances so that it will fit directly over our standard aluminum tubing, eliminating any mounting problems.

3¼" diam., 48" f.l. (uncoated) **$28.00**
Same as above with coating **$32.00**
4⅛" diam., 62" f.l. (uncoated) **$60.00**
Same as above with coating **$69.00**

We can supply ALUMINUM TUBING for the lenses above.

"BIG" ACHROMATIC TELESCOPE OBJECTIVES

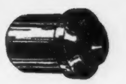
We have the largest selection of diameters and focal lengths in the United States available for immediate delivery. These are perfect magnesium-fluoride coated and cemented Gov't. surplus lenses made of finest crown and flint optical glass. Not mounted. Fully corrected. Tremendous resolving power. They can readily be used with eyepieces of only ¼" focal length, thereby producing high powers. Guaranteed well suited for astronomical telescopes, spotting scopes, and other instruments. Gov't. cost up to $100.

Diameter	Focal Length	Each
54 mm. (2⅛")	254 mm. (10")	$12.50
54 mm. (2⅛")	300 mm. (11.8")	12.50
54 mm. (2⅛")	330 mm. (13")	12.50
54 mm. (2⅛")	390 mm. (15.4")	9.75
54 mm. (2⅛")	508 mm. (20")	12.50
54 mm. (2⅛")	600 mm. (23½")	12.50
54 mm. (2⅛")	762 mm. (30")	12.50
54 mm. (2⅛")	1016 mm. (40")	12.50
54 mm. (2⅛")	1270 mm. (50")	12.50
78 mm. (3-1/16")	381 mm. (15")	21.00
80 mm. (3⅛")	495 mm. (19½")	28.00
81 mm. (3-3/16")	622 mm. (24½")	22.50
83 mm. (3¼")	660 mm. (26")	$28.00
83 mm. (3¼")	711 mm. (28")	28.00
83 mm. (3¼")	762 mm. (30")	28.00
83 mm. (3¼")	876 mm. (34½")	28.00
83 mm. (3¼")	1016 mm. (40")	30.00
102 mm. (4")	876 mm. (34½")	60.00
108 mm. (4¼")	914 mm. (36")	60.00
110 mm. (4⅜")*	1069 mm. (42-1/16")	60.00
110 mm. (4⅜")	1069 mm. (42-1/16")	67.00
128 mm. (5-1/16")*	628 mm. (24¾")	75.00
128 mm. (5-1/16")	628 mm. (24¾")	85.00

*Not coated

● We can supply ALUMINUM TUBING AND CELLS for the lenses above. ●

LOW-PRICE EYEPIECE



27-mm. E.F.L. Standard Kellner (wide-field) eyepiece offered in 1¼" black-anodized aluminum mount. Here is an astronomical eyepiece at a truly down-to-earth price. (For coated optics add 75 cents.) **$4.50 ppd.**

ASTRONOMICAL MIRRORS

These mirrors are of the highest quality, polished to ¼-wave accuracy. They are aluminized, and have a silicon-monoxide protective coating. You will be pleased with their performance.

	Diam.	F.L.	Postpaid
Plate Glass	3-3/16"	42"	$ 9.75
Pyrex	4¼"	45"	13.50
Pyrex	6"	60"	25.00

MIRROR MOUNT

Cast aluminum. Holds all our mirrors firmly with metal clips. Completely adjustable. Assembled, ready to use.

3-3/16"	Mirror Mount fits our 4½" tubing	$4.00 ppd.
4¼"	Mirror Mount fits our 5" tubing	4.00 ppd.
6"	Mirror Mount fits our 7" tubing	7.00 ppd.

Aluminum Telescope Tubing

O.D.	I.D.	Price Per Ft.
2¼"	2⅛"	$1.20 ppd.
3⅜"	3¼"	1.75 ppd.
4½"	4⅜"	2.50 f.o.b.
5"	4⅞"	2.25 f.o.b.
7"	6⅞"	3.00 f.o.b.

Focusing Eyepiece Mounts Rack & Pinion Type

The aluminum body casting is finished in black crackle paint and is machined to fit all our aluminum tubing. Has a chrome-plated brass focusing tube, which accommodates standard 1¼" eyepieces.

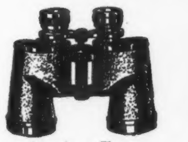
For 2⅛" I.D. Tubing	Postpaid	$12.95
For 3¼" I.D. Tubing	"	12.95
For 4⅜" I.D. Tubing	"	12.95

REFLECTOR TYPE FOR ALL SIZE TUBING: Complete with diagonal holder ...... $ 9.95

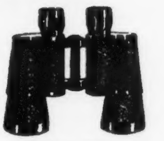
TELEVISION PROJECTION LENS

Brand New, f/1.9, E.F.L. 5 inches. Manufactured by Bausch & Lomb. We purchased entire lot of these discontinued units. Five elements, smallest lens 2", largest 4⅛". Completely assembled 6" in length. All surfaces hard coated. Get this BARGAIN now. **ONLY $22.50**

COATED BINOCULARS



American Type



"Zeiss" Type

Beautiful imported binoculars, precision made, at a low, low price. Above we have pictured the two most popular types. The American Type offers a superior one-piece frame and a clean design, pleasing to the eye. Complete with carrying case and straps. **Price plus 10% Federal tax.**

SIZE	TYPE	C. FOCUS	IND. FOCUS
6 x 15	OPERA	—	$12.75
6 x 30	"ZEISS"	$18.75	16.75
7 x 35	"ZEISS"	21.25	19.25
7 x 35	AMERICAN	23.50	—
7 x 35	AMERICAN WIDE ANGLE 10°	37.50	—
7 x 50	"ZEISS"	24.95	22.50
7 x 50	AMERICAN	32.50	—
8 x 30	"ZEISS"	21.00	18.25
10 x 50	"ZEISS"	30.75	28.50
20 x 50	"ZEISS"	41.50	39.50

MONOCULARS

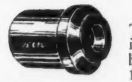
Brand new, coated optics, complete with pigskin case and neck straps.

	Price		Price
6 x 30	$10.00	7 x 50	$15.00
8 x 30	11.25	16 x 50	17.50
7 x 35	12.50	20 x 50	20.00

"MILLIONS" of Lenses, etc. Free Catalogue

We pay the POSTAGE — C.O.D.'s you pay postage. Satisfaction guaranteed or money refunded if merchandise returned within 30 days.

MOUNTED EYEPIECES



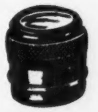
The buy of a lifetime at a great saving. Perfect war-surplus lenses set in black-anodized standard aluminum 1¼" O.D. mounts.

F.L.	TYPE	PRICE
6 mm. (¼")	Ramsden	$ 4.75
12.5 mm. (½")	Ramsden	4.50
12.5 mm. (½")	Symmetrical	6.00
16 mm. (⅝")	Erfle (wide angle)	12.50
16 mm. (⅝")	Triplet	12.50
18 mm. (¾")	Symmetrical	6.00
22 mm. (27/32")	Kellner	6.00
32 mm. (1¼")	Orthoscopic	12.50
35 mm. (1⅜")	Symmetrical	8.00
55 mm. (2-3/16")	Kellner	6.00
56 mm. (2¼")	Symmetrical	6.00

COATED LENSES 75 cents extra.

"GIANT" WIDE ANGLE EYEPIECES

ERFLE EYEPIECE (65° field) contains 3 coated achromats. 1½" E.F.L., clear aperture 2⅛". Has a focusing mount with diopter scale. Will make an excellent 35-mm. Kodachrome Viewer. Magnifies seven times ...... **$18.50 ppd.**



WIDE ANGLE ERFLE (68° Field) **EYEPIECE.** Brand new; coated 1¼" E.F.L. Focusing mount. 3 perfect achromats, 1-13/16" aperture **$18.50**

WIDE ANGLE ERFLE 1½" E.F.L. Brand new; contains Eastman Kodak's rare-earth glasses; aperture 2"; focusing mounts; 65° field **$18.50**

1¼" Diam. Adapter for Erfle eyepieces **$3.95**

LENS CLEANING TISSUE — Here is a wonderful Gov't. surplus buy of Lens Paper which was made to the highest Gov't. standards and specifications. 500 sheets size 7½" x 11" **$1.00**

90° RIGHT-ANGLE PRISMS

8-mm. face	$1.00	——	
12-mm. face	1.00	——	
23-mm. face	1.25	Silvered	$2.00
28-mm. face	1.75	Silvered	2.50
38-mm. face	2.00	Silvered	2.75
48-mm. face	3.00	Silvered	4.00

62-mm. face, coated **$17.50**

3X TELESCOPE — New Low Price!

Makes a nice low-priced finder. Brand new; has 1" Achromatic Objective. Amici Prism Erecting System, 1⅜" Achromatic Eye and Field Lenses. Small, compact, wt. 2 lbs.

Gov't. cost $200.

Uncoated ...... **$6.50** **Coated** **$10.50**

8-POWER ELBOW TELESCOPE

This M-17 telescope has a brilliant-image 48° apparent field — 325 feet at 1,000 yards. The telescope can be adjusted for focusing 15 feet to infinity. It has a 2" objective, focusing eyepiece 28-mm. focal length with an Amici erecting system. Turret-mounted filters: clear, red, amber, and neutral. Lamp housing to illuminate reticle for night-time use. Truly the biggest bargain you were ever offered. Original Gov't. cost $200.

8 x 50

BARGAIN PRICE ...... **$13.50 ppd.**

A. JAEGERS

6918 Merrick Road
LYNBROOK, N. Y.

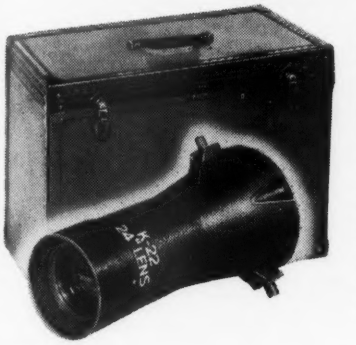
Sale! Terrific Bargains!

WAR-SURPLUS AERIAL CAMERA LENSES

24" Focal Length, f/6, in 23"-long Lens Cone

Made by Bausch & Lomb and Eastman Kodak

$39.50, Used; $59.00, New; Gov't. Cost $1,218.00



Here is a once-in-a-lifetime bargain opportunity in aerial camera lenses. Made by famous manufacturers for the Government and now no longer needed. These lenses are precision-mounted in the lens cone that was attached to the film-carrying part of the camera. Picture size was 9" by 9". The diaphragm is included, adjustable from f/6 to f/22 by a flexible rod (easily extended) near camera end of the cone. Diaphragm opens from about 1" to 3½".

Focal plane of lens is about 10" outside the end of the cone, making it easy to attach film holder, eyepiece, or the like. These 4"-diameter lenses are precision 4-element types, Aero Tessar or Aero Ektar (no choice), weighing 25 lbs. with cone. Fine trunklike carrying case weighs 26 lbs. Lens elements are in beautiful brass cells which screw into the diaphragm holder. Cell can be easily taken out of cone in a few minutes.

USES:

1. As a long-range, Big Bertha telephoto lens.
2. For visual richest-field telescope objective (wide field, low power) with one of our wide-field Erfle eyepieces. Not recommended for use above 24X unless stopped down to f/11. Use to see satellites, star clusters, star fields, and more.
3. As an opaque-projector lens.
4. For operation PHOTOTRACK.

OPERATION PHOTOTRACK

The Society of Photographic Scientists and Engineers is co-operating with the Smithsonian Astrophysical Observatory and the International Geophysical Year national committee in operation PHOTOTRACK — a project in which technically minded photographers are asked to aid in photographing the artificial satellites. For information, write to the society's secretary-treasurer, Norton Goodwin, 826 Connecticut Ave. N.W., Washington 6, D. C.

SALE AERIAL CAMERA LENSES

Lens Cones with f/6 24" focal length —

Stock #85,059-Y....24", Used......$39.50 f.o.b. Utah

Stock #85,060-Y....24", New......$59.50 f.o.b. Utah

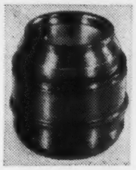
ALSO AVAILABLE

Lens Cones with f/8 40" focal length —

Stock #85,061-Y......Used...........$68.50 f.o.b. Utah

Stock #85,062-Y......New...........$89.50 f.o.b. Utah

Sale! GIANT ERFLE EYEPIECE



Wow! Here is a real bargain. We just bought a large lot of these eyepieces reasonably — so down goes the price to $9.95 for a real sale. Lens system contains 3 coated achromats over 2" in diameter. Gov't. cost over $100.00. Brand new, weight 2 pounds. The value will double when this sale is over, and triple and quadruple as years pass. If we didn't owe the bank so much money, we'd be tempted to hold onto these eyepieces. Their wide apparent field is 65°. The focal length is 1½". Lenses are in a metal cell with spiral threads; focusing adapter with 32 threads per inch is included; diameter is 2-11/16". If you don't order now and you miss out on a hundred-dollar eyepiece for only $9.95, you can't say that we didn't try to impress you with its value. You can make some super-duper finders with these eyepieces. They are also ideal for richest-field telescopes, which are becoming popular each day, particularly in the Sputnik age. Everyone with a large reflecting telescope should have one of these.

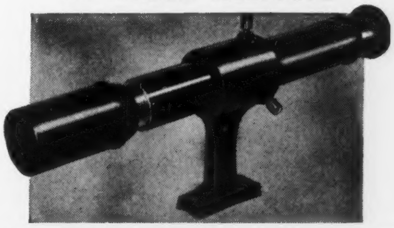
Stock #50,178-Y.................Sale Price $9.95 ppd.

3X ELBOW TELESCOPE

Sometimes the war-surplus end of this business is heartbreaking. Here is an excellent little telescope that cost Uncle Sam about $200.00. Makes a dandy finder with a 13° field. Weight 2 pounds, size 5¾" x 4½". Although our price has been only $7.50 postpaid, they just sit on our shelves year after year. Then to get an item we really wanted, we had to buy 200 more of these telescopes recently. Objective lens is an achromat, diameter 26 mm., focal length 104 mm. Amici roof prism with faces of 18 mm. x 20 mm. cost from $12.00 to $36.00 to make. Symmetrical eyepiece of 1¼" (32.5 mm.) effective focal length consists of 2 achromats with diameters of 34 mm. and focal lengths of 65 mm. At our new price we cannot afford to have our instrument man take these apart and clean them — so we told him to look them over to make sure everything is okay, and now you can buy them for only $5.00 each delivered to you.

Stock #50,179-Y...................................$5.00 ppd.

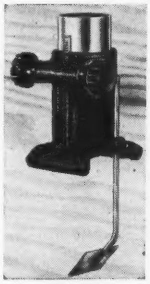
6X FINDER TELESCOPE



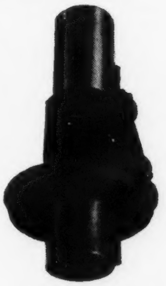
Has crosshairs for exact locating. You focus by sliding objective mount in and out. Base fits any diameter tube — an important advantage. Has 3 centering screws for aligning with main telescope. 20-mm.-diameter objective. Weighs less than ½ pound.

Stock #50,121-Y...................................$8.00 ppd.

Rack & Pinion Eyepiece Mounts



For Reflectors



For Refractors

Now you can improve performance in a most important part of your telescope — the eyepiece holder. Smooth, trouble-free focusing will help you to get professional performance. Look at all these fine features: real rack-and-pinion focusing with variable tension adjustment; tube accommodates standard 1¼" eyepieces and accessory equipment; lightweight aluminum body casting; focusing tube and rack of chrome-plated brass; body finished in black wrinkle paint. No. 50,077-Y is for reflecting telescopes, has focus travel of over 2", and is made to fit any diameter or type tubing by attaching through small holes in the base. Nos. 50,103-Y and 50,108-Y are for refractors and have focus travel of over 4". Will fit our 2⅞" I.D. and our 3⅞" I.D. aluminum tubes respectively.

Stock #50,077-Y (less diagonal holder)	**$9.95 ppd.**
Stock #60,035-Y (diagonal holder only)	**1.00 ppd.**
Stock #50,103-Y (for 2⅞" I.D. tubing)	**12.95 ppd.**
Stock #50,108-Y (for 3⅞" I.D. tubing)	**13.95 ppd.**

AERIAL CAMERA LENS

f/2.5 with 7" Focal Length

An excellent lens — can be adapted for use on 35-mm. and Speed Graphic cameras as a telephoto lens. Three of the first four pictures of Sputnik III were taken by a student with a homemade camera using one of these lenses. Adjustable diaphragm, f/16 to f/2.5. Gov't. cost over $400. War surplus

Stock #70,161-Y.......................$39.95 ppd.

7X FINDER TELESCOPE–ACHROMATIC

Stock #50,080-Y Finder alone, less ring mounts...$9.95

Stock #50,075-Y Ring mounts per pair..........$3.95

PRISM STAR DIAGONAL

For comfortable viewing of the stars near the zenith or high overhead with refracting telescopes using standard size (1¼" O.D.) eyepieces, or you can make an adapter for substandard refractors. Contains an excellent quality aluminized right-angle prism. Tubes are satin chrome-plated brass. Body is black wrinkle cast aluminum. Optical path of the system is about 3½".

Stock #70,077-Y.................................$12.00 ppd.

"MAKE-YOUR-OWN" 4¼" MIRROR KIT

The same fine mirror as used in our telescopes, polished and aluminized, lenses for eyepieces, and diagonal. No metal parts.

Stock #50,074-Y.................................$16.25 ppd.

MISCELLANEOUS ITEMS

KELLNER EYEPIECE — 2" focal length (1¼" O.D.). Mount of black anodized aluminum.

Stock #30,189-Y...........................$6.00 ppd.

60° SPECTROMETER PRISM — Polished surfaces 18-mm. x 30-mm. — flat to ½ wave length.

Stock #30,143-Y...........................$8.25 ppd.

ASTRONOMICAL TELESCOPE TUBING

Stock No.	I.D.	O.D.	Lgth.	Description	Price
80,038-Y	**4⅞"**	**5¼"**	**46"**	**Spiral-wound paper**	**$2.50**
85,008-Y	**6⅞"**	**7⅜"**	**60"**		**4.00**
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CELESTIAL CALENDAR

Universal time is used unless otherwise noted.

MINOR PLANET PREDICTIONS

Lutetia, 21, 9.0. July 26, 22:23.7 −15-10. August 5, 22:18.7 −16-03; 15, 22:11.3 −17-03; 25, 22:02.8 −17-59. September 4, 21:54.7 −18-43; 14, 21:48.3 −19-07. Date of opposition, August 22.

Interamnia, 704, 9.6. August 15, 23:28.6 +22-07; 25, 23:22.5 +22-58. September 4, 23:14.8 +23-20; 14, 23:06.4 +23-13; 24, 22:58.1 +22-39. October 4, 22:51.1 +21-44. Date of opposition, September 9.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0^h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

SUNSPOT NUMBERS

The following American sunspot numbers for May were derived by Dr. Sarah J. Hill of Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

May 1, 199; **2,** 211; **3,** 265; **4,** 240; **5,** 212; **6,** 172; **7,** 183; **8,** 153; **9,** 176; **10,** 180; **11,** 188; **12,** 148; **13,** 152; **14,** 107; **15,** 120; **16,** 117; **17,** 120; **18,** 130; **19,** 159; **20,** 161; **21,** 171; **22,** 158; **23,** 197; **24,** 206; **25,** 175; **26,** 173; **27,** 145; **28,** 153; **29,** 189; **30,** 179; **31,** 190. Mean for May, 171.9.

Below are observed mean relative sunspot numbers from Zurich Observatory and its stations in Locarno and Arosa.

June 1, 200; **2,** 154; **3,** 181; **4,** 195; **5,** 195; **6,** 176; **7,** 185; **8,** 200; **9,** 209; **10,** 200; **11,** 193; **12,** 193; **13,** 176; **14,** 160; **15,** 131; **16,** 100; **17,** 113; **18,** 100; **19,** 114; **20,** 107; **21,** 141; **22,** 148; **23,** 184; **24,** 189; **25,** 199; **26,** 183; **27,** 178; **28,** 174; **29,** 200; **30,** 159. Mean for June, 167.9.

OCCULTATION PREDICTIONS

August 8-9 **Delta Tauri** 3.9, 4:20.5 +17-26.7, 24. Im: **H** 11:02.3 −1.3. +0.2 117; **I** 11:14.8 −0.6 +1.7 79. Em: **H** 11:57.2 −0.5 +3.2 215.

August 8-9 **68 Tauri** 4.2, 4:23.1 +17-50.0, 24. Im: **H** 12:35.0 −1.3 +2.0 62.

For stations in the United States and Canada, usually for stars of magnitude 5.0 or brighter, data from the *American Ephemeris* and the *British Nautical Almanac* are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard-station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. **Lo,** lat. **L**) within 200 or 300 miles of a standard station (long. **LoS,** lat. **LS**). Multiply **a** by the difference in longitude (**Lo−LoS**), and multiply **b** by the difference in latitude (**L−LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

A	+72°.5,	+42°.5	**E**	+91°.0,	+40°.0
B	+73°.6,	+45°.5	**F**	+98°.0,	+31°.0
C	+77°.1,	+38°.9	**G**	Discontinued	
D	+79°.4,	+43°.7	**H**	+120°.0,	+36°.0
			I	+123°.1,	+49°.5

MINIMA OF ALGOL

August 1, 19:42; 4, 16:31; 7, 13:19; 10, 10:08; 13, 6:56; 16, 3:45; 19, 0:33; 21, 21:22; 24, 18:10; 27, 14:59; 30, 11:48.

September 2, 8:36; 5, 5:25; 8, 2:13.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

MOON PHASES AND DISTANCE

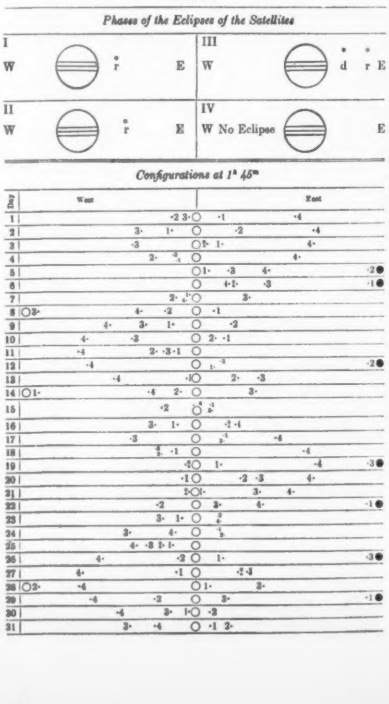
Last quarter	August 7, 17:49
New moon	August 15, 3:33
First quarter	August 21, 19:45
Full moon	August 29, 5:53
Last quarter	September 6, 10:24

	August	Distance	Diameter
Apogee	5, 18^h	251,300 mi.	29′ 33″
Perigee	17, 15^h	226,200 mi.	32′ 50″
	September		
Apogee	2, 11^h	251,900 mi.	29′ 29″

JUPITER'S SATELLITES

The configurations of Jupiter's four bright moons are shown below, as seen in an astronomical or inverting telescope, with north at the bottom and east at the right. In the upper part, *d* is the point of disappearance of the satellite in Jupiter's shadow; *r* is the point of reappearance.

In the lower section, the moons have the positions shown for the Universal time given. The motion of each satellite is from the dot toward the number designating it. Transits over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. The chart is from the *American Ephemeris and Nautical Almanac.*



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0^h Universal time on the respective dates.

Mercury comes to inferior conjunction with the sun on August 23rd, passing from the evening to the morning sky. Except for a few days at the beginning and end of the month, the planet is too near the sun to be seen.

Venus rises in the east-northeast about two hours before the sun. On the morning of the 13th the moon will be near this brilliant -3.3-magnitude planet, which will then be moving from Gemini into Cancer.

Mars is prominent in Aries, rising about 1½ hours before local midnight by August 15th. During the month Mars will brighten from magnitude -0.1 to -0.5. Telescopically, the red planet shows a gibbous disk 11″ in diameter. The moon is to be very close to Mars on the morning of the 7th, conjunction occurring at 9:45 UT, with Mars 1° 05′ south as seen from the center of the earth. Observers in parts of northern Canada will see the planet occulted.

Jupiter is in Virgo not far from Spica, at midmonth setting about an hour after evening twilight ends. Its magnitude is -1.4. In a telescope, the planet presents a slightly flattened disk with an equatorial diameter of 34″.

Saturn is in Ophiuchus east of Antares. On August 15th, this $+0.6$-magnitude planet crosses the meridian about half an hour after sunset, and on the 24th its motion among the stars changes from westward to eastward. The moon passes north of Saturn on the night of August 22-23.

Uranus will be too close to the sun in the sky to be viewed this month, conjunction occurring on August 4th.

Neptune is an 8th-magnitude object approximately 2° east of Kappa Virginis, setting about 2¼ hours after the sun on the 15th. This slowly moving planet will be at right ascension $14^h\ 02^m.8$, declination $-10°\ 38'$ (1958 co-ordinates) on that date.

Artificial satellite observing at dusk in August will be aided by the star chart in this issue; for predawn observing a chart from a December issue will be helpful.

W. H. G.

UNIVERSAL TIME (UT)

TIMES used in Celestial Calendar are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. To obtain daylight saving time subtract 4, 5, 6, or 7 hours, respectively. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown.

VARIABLE STAR MAXIMA

August 2, S Virginis, 132706, 7.1; 4, U Herculis, 162119, 7.6; 7, R Carinae, **092962**, 4.6; 10, R Draconis, 163266, 7.6; 12, S Carinae, **100661**, 5.7; 14, RR Sagittarii, **194929**, 6.6; 16, T Ursae Majoris, 123160, 7.9; 16, W Andromedae, 021143, 7.5; 19, Chi Cygni, 194632, 5.3; 25, RS Librae, **151822**, 7.7; 26, Z Puppis, **072820b**, 7.9.

September 3, RR Scorpii, **165030**, 6.0; 6, T Centauri, **133633**, 6.1.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

AUGUST METEORS

The moon, nearing new, will not interfere with observations of the Perseid meteor shower this year. During the first two weeks of August, the number of meteors increases to a peak on the 12th, when up to 50 per hour may be seen under favorable conditions. On the 12th the radiant is located at right ascension $3^h\ 04^m$, declination $+58°$.

W. H. G.

STARS FOR AUGUST

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of August, respectively; also, at 7 p.m. on September 7th. For other dates, add or subtract ½ hour per week.

Etamin, the bright star in the head of Draco, is on the meridian; now is an excellent time to trace this long constellation through the northern sky. The brightest star near the zenith is Vega, which marks compact Lyra, just west of the Northern Cross.

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